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fact sheet

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NUCLEAR POWER SOURCES ON SATELLITES IN OUTER SPACE

The Stockholm International Peace Research Institute (SIPRI) has since 1973 closely followed the developments in military space technology. An average of about 120 spacecraft are launched each year, and about 75 per cent of them are used for military purposes. Most of the spacecraft are launched either by the Soviet Union or the United States. The satellites are of several types: for military reconnaissance, communications, navigation, meteorological, geodetic and mapping missions. They continue to enhance the land-, sea- and air-based military forces of these countries. Satellites are used for gaining accurate targeting information. They are used for accurately guiding, for example, missiles, aircraft and naval ships carrying nuclear warheads to their targets. They are used for communications between military forces, over both short and long distances.

This Fact Sheet presents background information on one of these types of military satellite--one which is destined to crash into the earth's environment and which carries a nuclear reactor.

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Cosmos 1402

Once again attention has been focused on the use of outer space for military purposes. On 28 December 1982 a Soviet military ocean-surveillance satellite, Cosmos 1402, was split up during its 1926th orbit, into three components - the rocket, the main satellite, and the nuclear reactor (see figure 1). The reactor is usually then placed into a higher orbit where it circles the earth for some 500 years, a sufficient time for the short-lived radioactive fission products generated within the reactor to decay. But on this occasion attempts to do this failed and the section carrying the nuclear reactor has entered into an ever decreasing circular orbit which will bring it back into the earth's atmosphere.

Such accidents have occurred before. The most recent one was on 24 January 1978, when a similar Soviet satellite, Cosmos 954, entered the earth's atmosphere and partially burned up, contaminating the atmosphere with radioactivity. The remaining debris landed in northern Canada, contaminating parts of the land there. Another accident, resulting in substantial contamination of the atmosphere and the earth's surface, involved a US satellite. A US Navy satellite launched on 21 April 1964 carried a nuclear power generator which used plutonium-238. The spacecraft failed to orbit and the payload re-entered the earth's atmosphere in the Southern Hemisphere. The power generator was completely burned up during re-entry, and the resulting radioactive particles were distributed at about 50 km above the earth's surface. Some 95 per cent of the radioactivity eventually landed on the earth. Soil samples taken from 65 sites around the world between October 1970 and January 1971 showed that most of the plutonium-238 from the satellite power generator was deposited in the Southern Hemisphere. The fallout in this region was some 2.5 times that in the Northern Hemisphere. It is also interesting to note that plutonium-238 fallout from the satellite was nearly two times that which resulted from atmospheric nuclear tests conducted by the end of 1970.

In tables 1 and 2 the Soviet and the US spacecraft which have carried nuclear power sources are listed. It can be seen that a large fraction of these are military satellites.

The need for nuclear power on satellites

In order to increase the capability of military reconnaissance satellites, long-range radars, micro-wave and infra-red radiometers, radar altimeters, and other microwave devices are often used aboard satellites. Some of these are used to detect and track military surface ships (the main function of Cosmos 1402), while others are used to determine various ocean properties--the knowledge of which is essential, for example, for the development and the use of sensors needed for the detection and tracking of enemy submarines. These sensors require considerable power, as can be seen from table 3. In most satellites the power is generated by solar cells. However, many such cells have to be used so that the spacecraft experiences considerable drag, causing it to fall back to the earth's surface unless a large amount of fuel is spent to keep it up in orbit. Moreover, concern has recently been expressed because such large solar power panels become vulnerable to nuclear or beam weapon attack. In order to extend the life and efficiency of military satellites and make them capable of surviving nuclear attack and possible attack from hunter-killer satellites, considerable impetus was given to the development of nuclear power generators.

The two most commonly used nuclear energy sources are the energy released when a radionuclide decays and the energy released when a fissile atom fissions. In the former, the heat produced by decaying radionuclides can be converted into electricity in two ways: (a) by dynamic conversion using a turbogenerator, or (b) by static conversion mainly using thermoelectric devices. Of the more than 1,300 available radionuclides, only eight have characteristics suitable for use as power device fuels. Of these the most commonly used is plutonium-238, an alpha radiation emitter with a half-life of 87.8 years. In the centre of a typical radionuclide thermoelectric generator (RTG), there is a thick cylindrical fuel capsule which serves as the heat source. Surrounding the fuel capsule are thermoelectric energy converters. Such power sources have been used by both the USA and the Soviet Union on several satellites and deep space probes (tables 1 and 2). The power output has ranged from 2 watts to about 500 watts.

It can be seen from table 3 that the power generated by RTG sources is not enough for sensors such as the synthetic aperture radar. As an alternative, nuclear reactors have been developed both in the Soviet Union and in the USA for use in satellites. In the USA, under the programme known as Space Nuclear Auxiliary Power (SNAP), both RTGs and nuclear reactors have been developed. The first reactor ever to be placed in space, SNAP-10A, was orbited on 3 April 1965 at 13,000 km but it failed after 45 days. This reactor will re-enter the earth's atmosphere after about 4,000 years. Currently the USA is working on a reactor, SP-100, capable of producing 100 kilowatts compared to the power from SNAP-10A of about 30 kilowatts.

By the end of 1982 the Soviet Union had launched about 25 satellites carrying nuclear reactors. Their early reactors were known as Romashka and the recent ones are known as Topaz. Such reactors produce about 40 kilowatts of thermal power and they are fuelled with about 50 kg of highly enriched uranium. Since 1974 the Soviet Union has been operating two satellites at a time. Satellites are orbited in the same orbital plane but about 25 minutes apart. The USA uses four ocean-surveillance satellites at a time. Again, the satellites are in the same orbital plane but they are separated from each other in time and distance along their orbital paths. The use of such groups of satellites indicates that they are probably used to determine the position and velocity of the naval vessels being surveyed.

Implications

In response to concerns expressed during the first week of January 1983 regarding the re-entry of Cosmos 1402 into the earth's atmosphere, the Soviet news agency Tass announced on 7th January that the satellite "was divided into separated fragments by commands from earth in order to isolate the active part of the reactor, which ensured its subsequent complete combustion in the dense atmospheric strata". While this may be so, the radioactivity, however small, eventually will fall on the earth's surface, as past experience has shown. Contamination of the earth's environment from such sources is small at present, but in future this may not be the case as there are plans to orbit much larger nuclear reactors in space.

As a result of the last Cosmos 954 accident, President Carter pledged that the United States would pursue a ban on nuclear power in space. However, this position of the USA was later abandoned. The United Nations Sub-Committee on the Peaceful Uses of Outer Space examined the issues of nuclear power sources on board satellites. Both the United States and the USSR participated in this technical study. The main recommendation of the Sub-Committee was that appropriate measures for adequate radiation protection during all phases of a spacecraft carrying a nuclear power source should be mainly based on existing and internationally recognized standards recommended by the International Commission on Radiological Protection (ICRP). It is interesting to note here that one of the ICRP recommendations is that no space venture involving nuclear power sources should be undertaken unless its introduction results in positive benefit. It is difficult to imagine how the current practice of using nuclear power sources on military satellites--which mainly enhance the efficiency of weapons, particularly nuclear weapons, on earth--can have any positive benefit.

TABLE 1. NUCLEAR POWER GENERATORS ON US SATELLITES AND SPACE PROBES

Satellite	Date of Launch	Comments
1961		
USN Transit-4A (1961-01)	June 29	Test for developing integrated navigation system; first nuclear power supply; Pu-238 fuel
USN Transit-4B (1961-AH1)	Nov. 15	Similar to Transit-4A, SNAP-3, lifetime 8 months
1963		
USAF/USN (1963-38B)	Sep. 28	Navigation satellite
USAF/USN (1963-49B)	Dec. 5	Navigation satellite
1964		
USN navigation satellite	Apr. 21	Satellite failed to orbit; about 17 kCi of Pu-238 were distributed at about 50 km altitude; by 1970 about 95% of this was deposited on earth's surface; 1 kg of Pu-238 fuel
1965		
USAF Snapshot (1965-27A)	Apr. 3	First nuclear reactor launched into space; fuel was 93% U-235; thermal power output 35.5 kw
1968		
NASA Nimbus 2 weather satellite	May 18	Two power units were carried by the satellite but guidance malfunctioned and the satellite was exploded; power units recovered; Pu-238 fuel in each
1969		
NASA Nimbus 3 (1969-37A)	Apr. 14	Two power units were carried by the satellite; Pu-238 fuel
NASA Apollo 11 lunar module (1969-59C)	July 16	Early Apollo Scientific Experiment Package was kept warm during lunar night by two Pu-238 power sources
NASA Apollo 12 lunar module (1969-99C)	Nov. 14	Apollo Lunar Surface Experiment Package
1970		
Apollo 13 lunar module (1970-29C)	Apr. 11	The power source from the Lunar module was jettisoned in the South Pacific Ocean; no contamination was found; 3.8 kg of the Pu-238 fuel (44.6 kCi)

Satellite	Date of Launch	Comments
1971		
NASA Apollo 14 lunar module (1971-08C)	Feb. 1	Third lunar module landed on Feb.5, 1971; strontium-90 used as a fuel
NASA Apollo 15 lunar module (1971-63C)	July 26	Lunar module landed on the Moon on July 30, 1971
1972		
NASA Pioneer-10 (1972-12A)	Mar. 3	RTG, unmanned spacecraft flew by Jupiter in December 1973
NASA Apollo 16 lunar module (1972-31C)	Apr. 16	...
USAF Triad-01-1X transit navigation (1972-69A)	Sep. 2	RTG power generator
NASA Apollo 17 lunar module (1972-96C)	Dec. 7	...
1973		
NASA Pioneer-11 (1973-19A)	Apr. 6	Spacecraft flew by Jupiter in December 1974 and will encounter Saturn in September 1979
1975		
NASA Viking-1 lander (1975-75G)	Aug. 20	RTG; lander landed on Mars on July 20, 1976
NASA Viking-2 lander (1975-83C)	Sep. 9	Lander landed on Mars on Sep. 3, 1976
1976		
USAF Les-8 (1976-23A)	Mar 15	RTG power generator
USAF Les-9 (1976-23B)	Mar 15	RTG power generator

TABLE 2. NUCLEAR POWER GENERATORS ON SOVIET SATELLITES

Satellite Name and Designation	Launch Date	Orbital Inclination (°)	Perigee Height (km)	Apogee Height (km)	Comments
1965					
Cosmos 80-84 (1965-70A-E)	Sep. 18	56	1 357- 1 466	1 555- 1 576	Communications satellites; power source in one of the five satellites; probably used cerium-144 as fuel
Cosmos 86-90 (1965-73A-E)	Sep. 18	56	1 277- 1 373	1 638- 1 689	Communications satellites; power source in one of the five satellites; probably used cerium-144 as fuel
1967					
Cosmos 198 (1967-127A)	Dec. 27	65, 65	249 894	270 952	...
1968					
Cosmos 209 (1968-23A)	Mar. 22	65, 65	183 871	343 944	...
1970					
Cosmos 367 (1970-79A)	Oct. 3	65, 65	250 922	280 1 024	Moved to its higher orbit rapidly so that the orbital parameters of this orbit were announced
Luna 17/Lunokhod 1 (1970-95A)	Nov. 10	-	-	-	RTG power generator
1971					
Cosmos 402 (1971-25A)	Apr. 1	65, 65	247 948	274 1 036	...
Cosmos 469 (1971-117A)	Dec. 25	65, 65	249 941	262 1 023	...
1972					
Cosmos 516 (1972-66A)	Aug. 21	65, 65	251 920	263 1 030	...
1973					
Cosmos 626 (1973-108A)	Dec. 27	65, 65	257 910	259 990	...
Luna 21/Lunokhod 2 (1973-01A)	Jan. 8	-	-	-	RTG power generator
1974					
Cosmos 651 (1974-29A)	May 15	65, 65	250 892	264 954	...
Cosmos 654 (1974-32A)	May 17	65, 65	248 913	265 1 024	...
1975					
Cosmos 723 (1975-24A)	Apr. 2	65, 65	249 916	266 951	...
Cosmos 724 (1975-25A)	Apr. 7	65, 65	248 870	266 934	...

Satellite Name and Designation	Launch Date	Orbital Inclination (°)	Perigee Height (km)	Apogee Height (km)	Comments
Cosmos 785 (1975-116A)	Dec. 12	65, 65	251 898	261 1 023	...
1976					
Cosmos 860 (1976-103A)	Oct. 17	65, 65	252 919	265 1 008	...
Cosmos 861 (1976-104A)	Oct. 21	65, 65	251 919	265 1 005	...
1977					
Cosmos 937 (1977-77A)	Aug. 24	65	424	444	...
Cosmos 952 (1977-88A)	Sep. 16	65, 65	251 910	265 998	...
Cosmos 954 (1977-90A)	Sep. 18	65	251	265	The satellite crash-landed in Canada with parts of its nuclear reactor
1980					
Cosmos 1176 (1980-34A)	Apr. 29	65, 65	250 870	266 966	First nuclear reactor launched since the accident in 1978
1981					
Cosmos 1249 (1981-21A)	Mar. 5	65, 65	252 898	256 985	...
Cosmos 1266 (1981-37A)	Apr. 21	65, 65	249 891	268 965	...
Cosmos 1299 (1981-81A)	Aug. 24	65, 65	248 910	267 984	...
1982					
Cosmos 1365 (1982-43A)	May 14	65	252	264	Manoeuvred into higher orbit on 27 September 1982
Cosmos 1372 (1982-52A)	June 1	65, 65	246 908	270 981	...
Cosmos 1402 (1982-84A)	Aug. 30	65	251	265	Reactor could not be placed in higher orbit; expected to enter the earth's atmosphere by the end of January or early February 1983
Cosmos 1412 (1982-99A)	Oct. 2	65	251	266	Manoeuvred into higher orbit on 10 November 1982

Note: The second figure in the orbital inclination, perigee height and apogee height columns is that of the final orbit.

TABLE 3. POWER REQUIREMENT FOR VARIOUS SENSORS AND EQUIPMENT ABOARD OCEAN-SURVEILLANCE SATELLITES

Sensor or Equipment	Power (Watts)
Microwave scatterometer	30
IR radiometer	7
Microwave radiometer	20
Synthetic aperture radar	3 400
TV sensor	150
Multispectral camera	160
Recording equipment on board	115
UHF communications link	5.4
S-band communications link	1.2
Total	3 888.6

Source: "The Potential of Observation of the Oceans from Space", report prepared for the National Council on Marine Resources and Engineering Development, Executive Office of the President, December 1967.

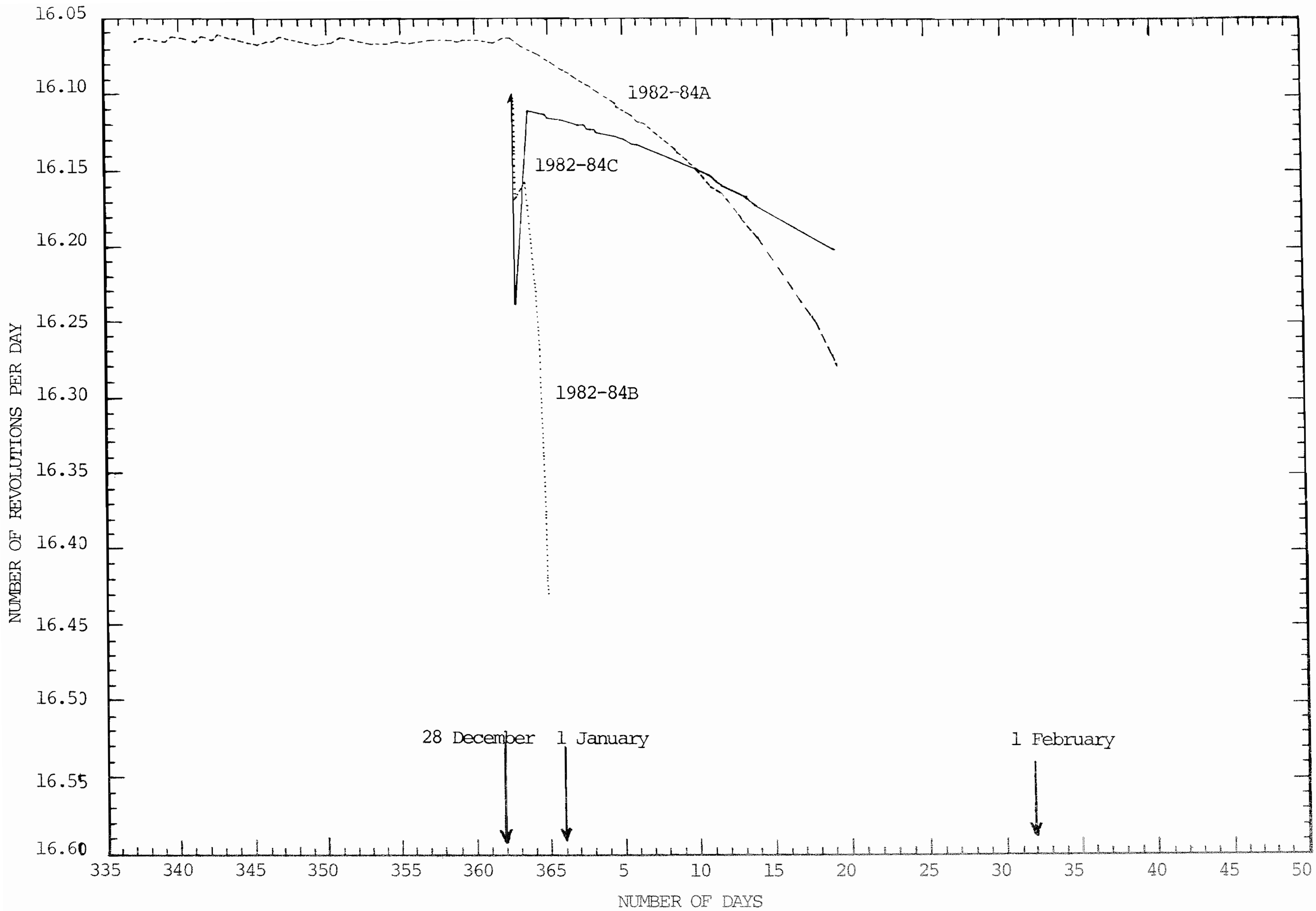

Figure 1. Number of revolutions made by Cosmos 1402 each day over a period of between December 1982 and January 1983 are shown. It can be seen that on 28 December the satellite (1982-84A) separated from its rocket (1982-84B) and the reactor (1982-84C). The rocket entered the earth's atmosphere on 30 December1982 and according to Pravda,16 December 1983. the satellite is expected to enter the atmosphere by the end of January 1983 and the reactor by the middle of February 1983. Extrapolation of curve 1982-84A suggests about 24 January as