

Radiation Detectors: Plastic Nuclear Track Detectors (PNTD)

Hardware Description

Measurement of the high-LET (linear energy transfer) particle radiation is passively accomplished with plastic radiation detectors. Plastics used are cellulose nitrate (CN) and Lexan® polycarbonate. The minimum LET value that can be detected with these plastics is ~100 keV/μm Tissue. Plastic films used in detectors have a thickness of 100 μm (CN) and 250 μm (Lexan). The films are layered together in various combinations and placed about the interior of the spacecraft to measure the flux, integral LET spectrum and spatial distribution of HZE (high-energy ionized) particles.

Latent particle tracks in the plastics are developed by chemically etching the exposed films. In this process, the damaged region along the path of the particle is preferentially attacked by the etchant. The resulting track appears as a hole in the plastic film, whose size is determined by the duration of the development process.

Cosmos 782: On Cosmos 782, two different PNTD configurations were used to make measurements. Thin detectors consisting of seven layered thin plastic films, held together with tape, measured the flux and integral LET spectrum. Thin stacks measured 5 cm² and 0.15 cm thick. Aluminized mylar was wrapped around the stack to protect the plastics from any ultraviolet light exposure. A total of twelve detectors were placed on centrifuged and stationary containers housing U.S. carrot culture and Killifish development experiments. Thick detector stacks consisting of 75 layered plastic films measured the charge spectrum. The thick stacks were 9 cm² and 2 cm thick. Two thick detectors were placed on the stationary platform inside the biosatellite. Only PTND stacks were used for radiation measurements onboard Cosmos 782.

Cosmos 936: On Cosmos 936, PTND stack configurations were flown in conjunction with a variety of other radiation detectors (see *Cosmos 936 Radiation Detector Packets*). Two films of each type of plastic were layered together and sealed, along with three nuclear emulsion films sealed in plastic, inside a black polyethylene envelope, to measure HZE flux, integral LET spectrum, and spatial distribution. The area of the plastic films was 4.5 x 6 cm. Eighteen detectors were located inside the U.S.-U.S.S.R. flight container: twelve detectors were attached in pairs to each of the six faces of a pyrel foam cube (7.7 cm³) centrally located in the joint portion of the flight package; and six detectors were attached to the face of the U.S. package at one end the container. To measure the Z spectrum, a stack composed of 97 μm thick layers of CN and 188 μm thick layers of Lexan was located in the joint portion of the flight container; the layer sequence was ten layers of CN, 200 layers of Lexan, 65 layers of CN, 200 layers of Lexan, and ten layers of CN.

Other Cosmos Missions: On subsequent Cosmos missions (Cosmos 1129, 1887, and 2044), PNTD stacks were flown on both the interior and exterior of the biosatellite. The plastics used in these stacks differ with the experiment objectives and evolving dosimetry materials/techniques. See *Cosmos 1129 Radiation Detector Packets*, and *Cosmos 2044* and *1887 Radiation Dosimeters* for more details.

Specifications

Dimensions: 100 μm (CN); 250 μm (Lexan)

Weight: Variable

Power: None

Data Acquisition

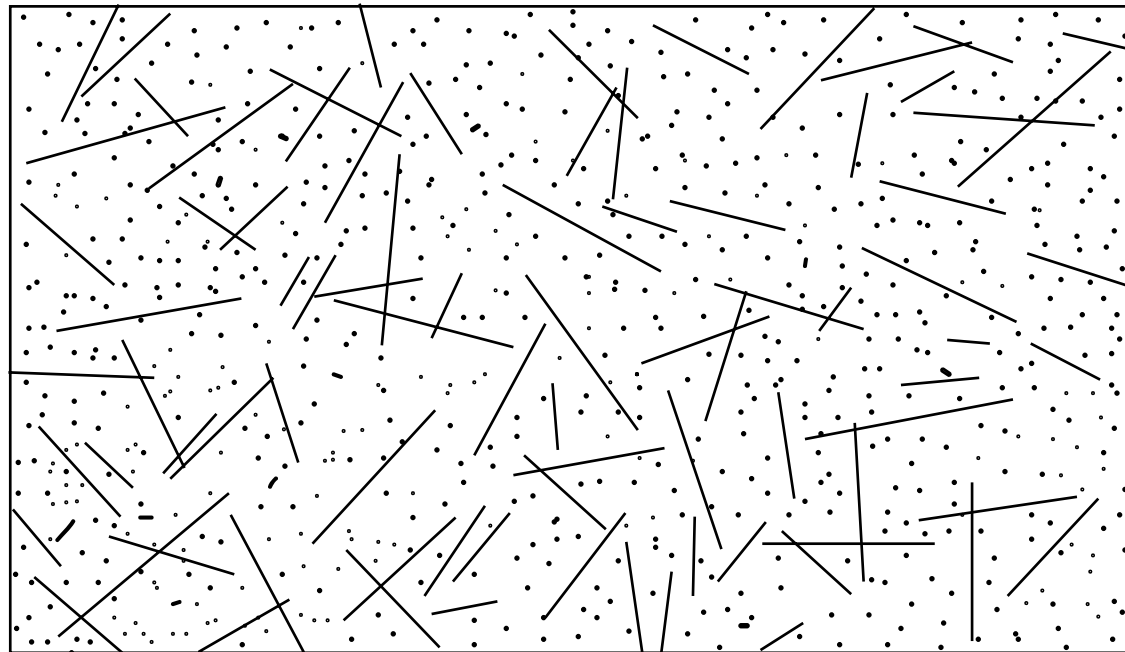
Radiation data

Related Ground-Based Hardware

High-Resolution Optical Microscope: Used to measure the depth and projection of the track in the plastic films. Track measurements are typically made at magnifications of 200-1,000x. Precision is in the order of ± 1μm.

Publications

- Peterson, D.D. et al.: HZE Particle Dosimetry. *Final Reports of U.S. Experiments Flown on the Soviet Satellite Cosmos 782*. NASA TM 78525: 160-178, 1978.
- Benton, E.V. et al.: Space Radiation Dosimetry on Board Cosmos 936. *Final Reports of U.S. Experiments Flown on the Soviet Satellite Cosmos 936*. NASA TM 78526: 184-245, 1978.



Positions of Measured Particle Tracks in the Cellulose Nitrate (CN)
Layer of the PNTD Stack Flown on Cosmos 936

**Missions Flown Through 1990: Cosmos 782 (p. 116), Cosmos 936 (p. 123), Cosmos 1129 (p. 128), Cosmos 1887 (p. 145),
Cosmos 2044 (p. 150)**

Radiation Detectors: Cosmos 1129 Radiation Detector Packets

Hardware Description

The detector packets include stacks of plastic nuclear track detectors (PNTDs) for measurements of high-LET (linear energy transfer) particles ($Z \geq 6$), and thermoluminescent detectors (TLDs) and radiator foil detectors for measurement of total doses due to charged particles and gamma rays.

Cosmos 1129 Corner Stacks The corner stacks are designed to contain both TLDs, for measuring the total absorbed dose, and particle radiator detectors, for measuring the neutron fluences.

Interior Plastic Stacks: The PNTD stacks in the interior of the spacecraft consist of alternating layers of three different detector types. A single repeat contains four ordered layers of the plastic types: GE Lexan polycarbonate, American Acrylics CR-39, Lexan, and Kodak Pathe cellulose nitrate (CN); with respective nominal layer thicknesses of 190 μm , 1,000 μm , 190 μm , and 100 μm . This sequence is repeated a sufficient number of times to comprise the entire thickness of each of the stacks. The arrangement of the plastic stacks along the three orthogonal directions is the preferred configuration because of the somewhat anisotropic response of the detectors (they responded to lower LET particles at normal incidence than at grazing incidence).

Exterior Plastic Stacks: The exterior PNTD stacks consist of alternating layers of Lexan and CN sandwiched between the two layers of CR-39. These packages are maintained outside the spacecraft. One surface of each stack is exposed directly to the space environment except for a very thin evaporated layer of aluminum to reduce the UV exposure and temperature during the mission.

Exterior TLD Packets: The external TLD packets contain six TLD chips each of ${}^7\text{LiF}$ and CaF_2 for total absorbed dose measurements outside the hull of the spacecraft. The TLD chips are held in twelve square milled holes, 0.635 cm in dimensions, in an aluminum plate. The two TLD types are placed in alternate spaces and are spread, approximately equally, across the external packet dimension. An aluminum top plate, 0.318 cm thick, protects the TLDs from the external environment.

Specifications

Dimensions: Various

Weight: Various

Power: None

Data Acquisition

Radiation data

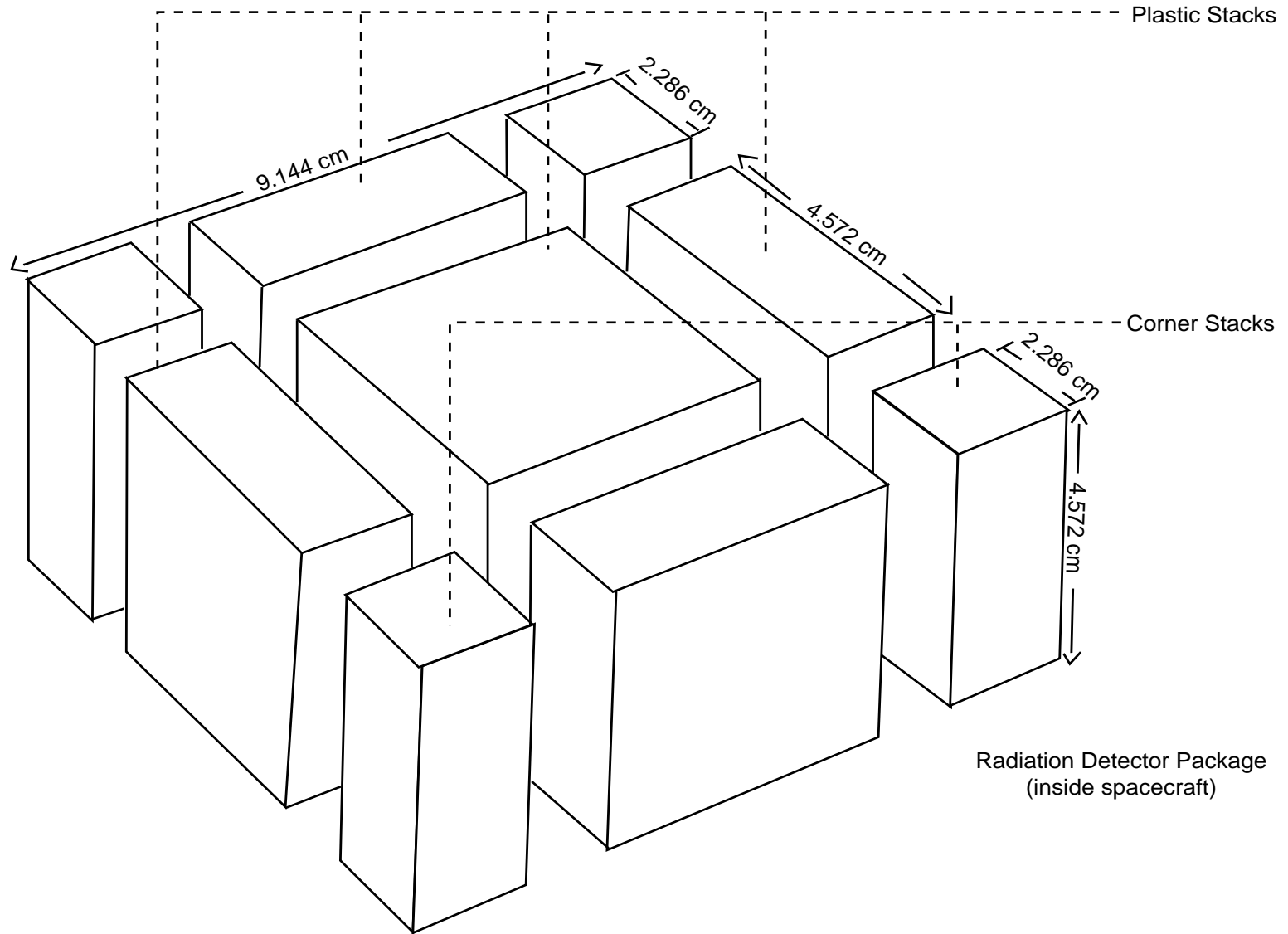
Related Ground-Based Hardware

High-Resolution Optical Microscope: Used to measure the depth and projection of the track in the plastic films. Track measurements are typically made at magnifications of 200-1,000x. Precision is on the order of $\pm 1 \mu\text{m}$.

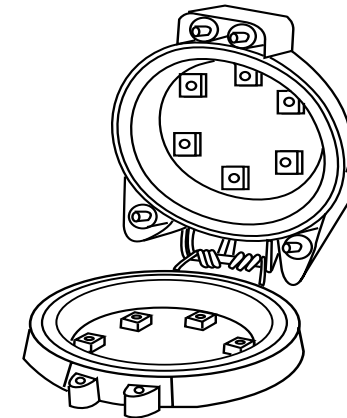
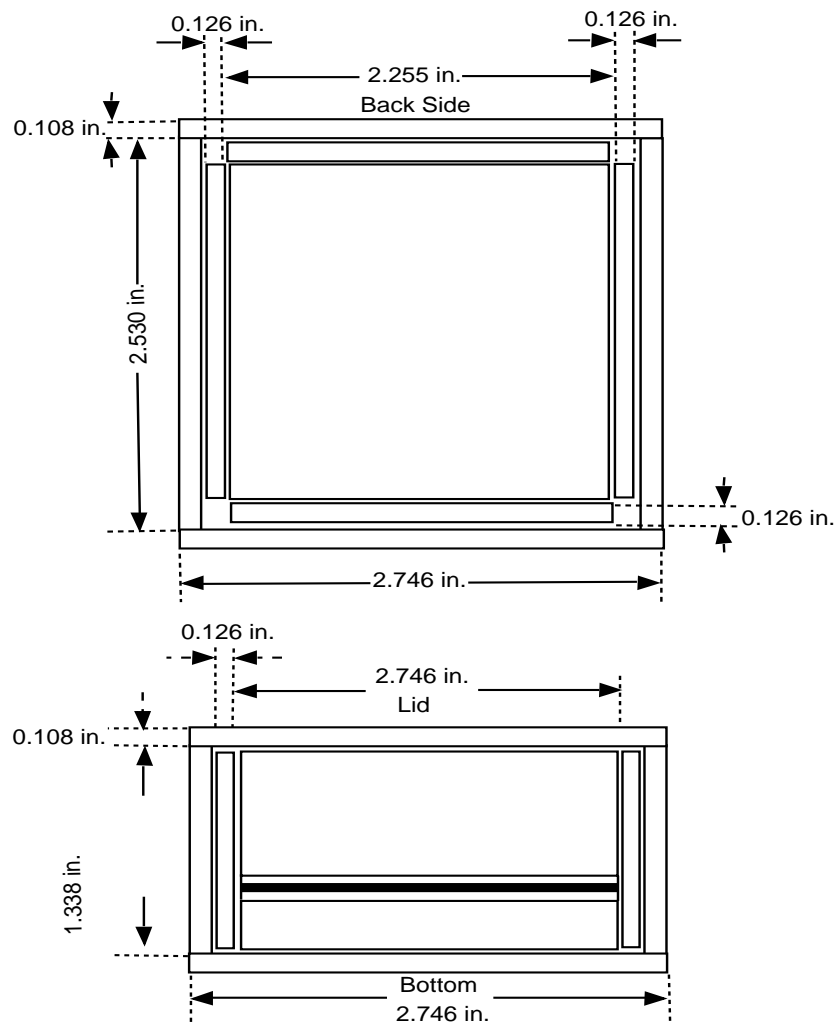
Publications

- Benton, E.V. et al.: Space Radiation Dosimetry Aboard Cosmos 1129. *Final Reports of U.S. Plant and Radiation Dosimetry Experiments Flown on the Soviet Satellite Cosmos 1129*. NASA TM-81288: 123-188, 1981.

Radiation Detectors: Cosmos 1129 Radiation Detector Packages



Missions Flown Through 1990: Cosmos 1129 (p. 128)



Clamshell style container includes sealed plastic stacks (SPSS) and an outside activation foil assembly (OAF).

Lexan box detector assembly (LBDA) contains plastic nuclear track detectors (PTNDs), thermoluminescent detectors (TLDs), and nuclear emulsion detectors.

Hardware Description

A set of radiation dosimetry and spectrometry measurements were conducted using passive detector systems located inside and outside the Cosmos 2044 spacecraft. Various versions of the different components of these systems were flown in different arrangements on other Cosmos missions (see *Cosmos 936 and 1129 Radiation Detector Packets*, and *Cosmos 1887 Radiation Dosimeters* for more details). All detectors for outside the spacecraft were mounted on aluminum plates and held in “clamshell”-style containers which were opened after reaching orbit and closed before re-entry to prevent heating of detectors in the atmosphere.

Thermoluminescent Detector Assembly (TDA): TDAs are designed to measure the depth dose under very thin shielding and help determine what fraction of the dose was due to low energy electrons versus heavy charged particles. A total of twelve thermoluminescent detector (TLD) stacks are attached to the outside of the spacecraft. Each stack was composed of both thin (0.02395 g/cm^2) and thick (0.2322 g/cm^2) TLD extruded chips. Thin TLDs are used to a depth of 0.5175 g/cm^2 , and thick TLDs at greater depths. A double-window of $7.5 \mu\text{m}$ thick Kapton polyimide films, both aluminized to an optical density of three, shield the TLDs from sun and space.

Sealed Plastic Stacks (SPS): Two hermetically sealed flight units containing plastic nuclear track detector (PNTD) and nuclear emulsion stacks measure the low energy, heavy particle (excluding electrons) LET (linear energy transfer) spectra under very thin shielding, as a function of depth. PNTD stacks are 3 cm in diameter and include sets of CR-39 and Cronar polyester detectors. Emulsion stacks are enclosed with ATR-4 temperature probes in thin stainless steel cylinders of the same diameter. The units are placed outside the spacecraft.

Activation Foil Assembly (AFA): The outside foil assembly measures neutron fluences outside the spacecraft. The two flight units contain ^{59}Co activation foils and PNTD films. An aluminum frame with aluminized Kapton double-windows are placed above the detectors, while the sides of the units were left open to vacuum. PNTDs of Cronar polyester allow comparison between those open to vacuum and those hermetically sealed (SPS, above). The inside foil assembly uses a single ^{59}Co activation foil to measure neutron fluences inside the spacecraft.

Fission Foil Assembly (FFA): Fission foils of ^{232}Th , in conjunction with solid state nuclear track detectors of muscovite mica, measure high energy ($>1\text{MeV}$) neutron fluxes and dose equivalent rates. Each of the two flight units are composed of four ^{232}Th fission foils with mica (1.27 cm diameter) in an aluminum and Lexan polycarbonate holder. The arrangement of the foils is mica/ ^{232}Th /mica, with lead discs of 0.5 mm thickness placed on each side for reduction of radiation from the ^{232}Th foils. The units are placed outside the spacecraft.

Neutron Detector Assembly (NDA): Layers of ^6LiF -TLDs in conjunction with CR-39 PNTDs measure the thermal ($<0.2 \text{ eV}$) and resonance ($0.2\text{eV}<E_n<1 \text{ MeV}$) neutron fluxes and dose equivalent rates. Each of the two flight units is composed of two ^6LiF layers with CR-39 (1.27 cm square) in an aluminum, polycarbonate holder. The arrangement of components is CR-39/ ^6LiF /CR-39, with Gd foil of 0.0025 cm thickness around one of the detectors to absorb thermal neutrons and allow separation of thermal and resonance neutrons.

Specifications

Dimensions: 1.0 x 1.5 cm diameter (TDA)

Weight: 2 g (TDA)

Power: None

Dimensions: 1.91 x 5 cm diameter (SPS)

Weight: 92 g (SPS)

Dimensions: 5.1 x 5.1 x 1 cm (AFA)

Weight: 165 g (AFA)

Dimensions: 3.5 x 3.5 x 0.54 cm (FFA)

Weight: 13 g (FFA)

Dimensions: 3.8 x 1.9 x 0.54 cm (NDA)

Weight: 8 g (NDA)

Data Acquisition

Spacecraft internal and external radiation data

Related Ground-Based Hardware

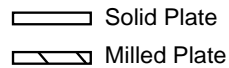
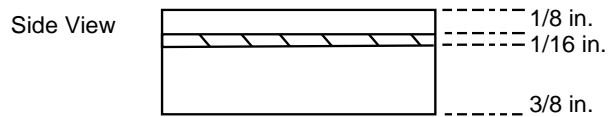
High-Resolution Optical Microscope: Used to scan nuclear emulsions, and polyester, polycarbonate and CR-39 PNTDs with pairs of CR-39 films in flight configurations for determination of short- and long-range tracks.

TLD Reader: Employs a thirty-second read cycle and $10^\circ\text{C}/\text{sec}$ temperature ramp. Total glow peak distributions are recorded on a microcomputer, for glow peak deconvolution.

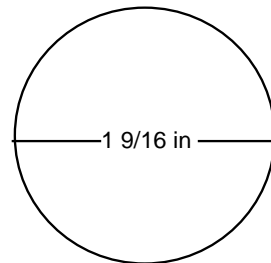
Spectrometer: With a high-sensitivity, very low background gamma ray is used to scan ^{59}Co foils.

Publications

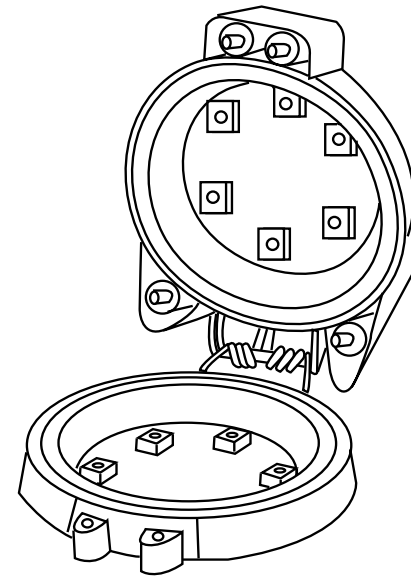
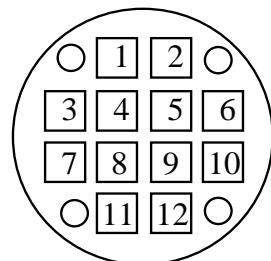
- Benton, E.V., et al.: Radiation Experiments on Cosmos 2044. *Final Reports of U.S. Experiments Flown on the Soviet Biosatellite Cosmos 2044, vol. 2*. J.P. Connolly, R.E. Grindeland, and R.W. Ballard, eds., NASA TM-108802, September 1994, pp. 387–424.



Top View of Solid Plate



Top View of Milled Plate



Clamshellstyle container includes TDAs, sealed plastic stacks (SPSs), an activation foil assembly (AFA), and a fission foil assembly (FFA).

Thermoluminescent detectors (TLDs) are assembled in units of 12 to form the thermoluminescent detector assembly (TDA)

Li^7 F TLDs are in 1, 3, 5, 8, 10, and 12.

CaF_2 TLDs are in 2, 4, 6, 7, 9, and 11.

Missions Flown Through 1990:Cosmos 2044 (p. 162)