Proton Launch System Mission Planner's Guide

APPENDIX A

Proton Launch System Description and History

A. PROTON LAUNCH SYSTEM DESCRIPTION AND HISTORY

A.1 GENERAL DESCRIPTION OF THE PROTON FAMILY

The Proton is currently available to commercial Customers as the four-stage Proton M/Breeze M configuration. Multiple payload fairing designs are presently qualified for flight.

The lower three stages of the Proton are produced by the KhSC plant in Moscow. KhSC also produces the Breeze M Upper Stage, the carbon composite PayLoad Adapter (PLA) structures and the PayLoad Fairings (PLFs). Production capacity for the commercial Proton is approximately eight vehicles per year.

The overall heights of the vehicle is approximately 60 m (197 ft), while the diameter of the second and third stages, and of the first stage core tank, is 4.1 m (13.5 ft). Maximum diameter of the first stage, including the outboard fuel tanks, is 7.4 m (24.3 ft). The Breeze M has a diameter of 4.0 m (13.1 ft). Total mass of the Proton at launch is approximately 705,000 kg (1,554,200 lbm).

The general characteristics of the Proton M Breeze M are shown in Table A.1-1.

Table A.1-1: Proton M/Breeze M General Characteristics

Parameter	Value
LV Lift-off Mass (Metric Tons, MT)	705
Payload Mass for 3-stage LV without Upper Stage (MT) $H_{circ.}$ = 180 km, i = 51.5°	23.0
GSO Payload Systems Mass (MT) $H_{circ.}$ = 35786 km, i = 0°	3.25
Geostationary Transfer Orbit Payload Systems Mass (MT) H_a = 35786 km, i = 7° to 31° (V_{SC} = 600 m/s to 1800 m/s)	4.2 to 6.92
Payload Bay Volume (m^3)	89 (Standard PLF, L = 15.255 m)
LV Structure Mass First Stage (MT) Second Stage (MT) Third Stage (MT) Breeze M (MT)	 30.6 11.0 3.5 2.5
Propulsion System Performance (Maximum Vacuum Thrust) First Stage (MN) Second Stage (MN) Third Stage (kN) Breeze M (kN)	 11.0 2.4 583.0 19.6

Note: All performance parameters are based on a spherical Earth radius of 6378 km.

A.2 PROTON M LV

An isometric view of the Proton three-stage booster with Breeze M Upper Stage showing the relationships among the major hardware elements is provided in Figure A.2-1. All three LV stages (and the Breeze M) use nitrogen tetroxide (N_2O_4) and unsymmetrical dimethylhydrazine (UDMH) as propellants.

A.2.1 Proton First Stage

The Proton M first stage consists of a central tank containing the oxidizer, surrounded by six outboard fuel tanks. Although these fuel tanks give the appearance of being strap-on boosters, they do not separate from the core tank during first stage flight. Each fuel tank also carries one of the six RD-276 engines that provide first stage power. Total first stage sea-level thrust is approximately 10.0 MN (2.25 x 10^6 lbf) with a vacuum-rated thrust level of 11.0 MN (2.47 x 10^6 lbf). Total first stage dry mass is approximately 30,600 kg (67,460 lbm); total first stage propellant load is approximately 428,300 kg (944,240 lbm).

The RD-276 engines now used on all Proton first stages are up-rated from the RD-275 design. Lift-off thrust on the engines of the first stage of Proton M has been increased by 5%, or 12% above the original RD-253 engine design. This enhancement was accomplished primarily through a minor modification to the propellant flow control valves. This modification first flew in July 2007. Engines incorporating this change have undergone extensive additional qualification firings since then, in order to approve them for use in standard production vehicles. As of 31 July 2009, a total of six Proton M LVs have flown with the RD-276 engine using the 112% thrust modification. Other than the changes to the propellant flow control valves, pressure feedback sensor and gas generator, the engines on the first stage of the Proton M LV are unchanged in their design and manufacture since 1965.

The propellant feed systems of the first, second and third stages of the Proton M have been simplified and redesigned in order to reduce propellant residuals in these stages by 50%, and a propellant purge system has been added to dump all residuals from the spent first stage before it returns to the earth's surface.

While a reduction in unusable propellants results in a performance gain, the primary rationale for the increased utilization of propellants is to minimize the environmental effects of the impact of the first and second stages in the downrange land-based hardware drop zones.

A.2.2 Proton Second Stage

The second stage, of conventional cylindrical design, is powered by three RD-0210 engines and one RD-0211 engine, developing a total vacuum thrust of 2.4 MN, or 5.4 x 10^5 lbf. The RD-0211 engine differs from the RD-0210 engine in that it accommodates a gas generator heat exchanger to supply pressurant gas to the fuel and oxidizer tanks. Total second stage dry mass is approximately 11,000 kg (24,250 lbm). Total second stage propellant load is approximately 157,300 kg (346,800 lbm).

A.2.3 Proton Third Stage

The third stage is equipped with one RD-0213 main engine (a non-gimbaled version of the RD-0210), developing 583 kN (1.3 x 10^5 lbf) thrust, and one RD-0214 control engine with four gimbaled nozzles, developing 31 kN (7.0 x 10^3 lbf) thrust. Total third stage dry mass is approximately 3,500 kg (7,700 lbm). Total third stage propellant load is approximately 46,562 kg (102,650 lbm).

A.2.4 Proton Flight Control System

Guidance, navigation, and control of the Proton M during operation of the first three stages is carried out by a single-fault-tolerant majority-voting closed-loop digital avionics system mounted in the Proton's third stage. This self-contained inertial control system uses a precision three-axis gyro-stabilizer and an on-board digital computer. This system also provides for flight termination in the event of a major malfunction during ascent.

The Proton M's digital flight control system is based on modern avionics technology. The new system allows for simplified control algorithm loading and test. It also enables greater ascent program design flexibility with respect to vehicle pitch profile and other parameters.

A.3 BREEZE M UPPER STAGE

The Breeze M Upper Stage, which is derived from the Breeze K Upper Stage flown on the Rokot, offers substantially improved payload performance and operational capabilities over the Block DM flown on the Proton K. The Breeze M program was initiated in 1994 by the Khrunichev Space Center and the Russian government. An isometric view of the Proton M/Breeze M is shown in Figure A.3-1. The layout and dimensions of the integrated Proton M/Breeze M space rocket are shown in Figure A.3-2.

The Breeze M is 2.65 meters in height and 4.0 meters in diameter, with a dry mass of 2,500 kg and a total propellant mass of 19,800 kg. It consists of the following three main elements:

1) A core section (central block) derived from the original Breeze K that accommodates a set of propellant tanks, the propulsion system, and the avionics equipment bay. Total propellant capacity of the core is 5.2 metric tons.

2) A toroidal Auxiliary Propellant Tank (APT) that surrounds the core section, and which is jettisoned in flight following depletion of its 14.6 metric tons of propellant. The application of the APT substantially improves the performance of the Breeze M stage.

3) A lower spacer used for mounting the Breeze M (at 4100 mm diameter) and payload fairing (at 4350 mm diameter) on the LV third stage; the spacer is jettisoned together with the LV third stage rocket.

Figures A.3-1 and A.3-2 illustrate the layout and dimensions of the Breeze M. Further details of the main elements of the Breeze M are given below.

Figure A.3-1: Proton M/Breeze M LV Major Hardware Elements

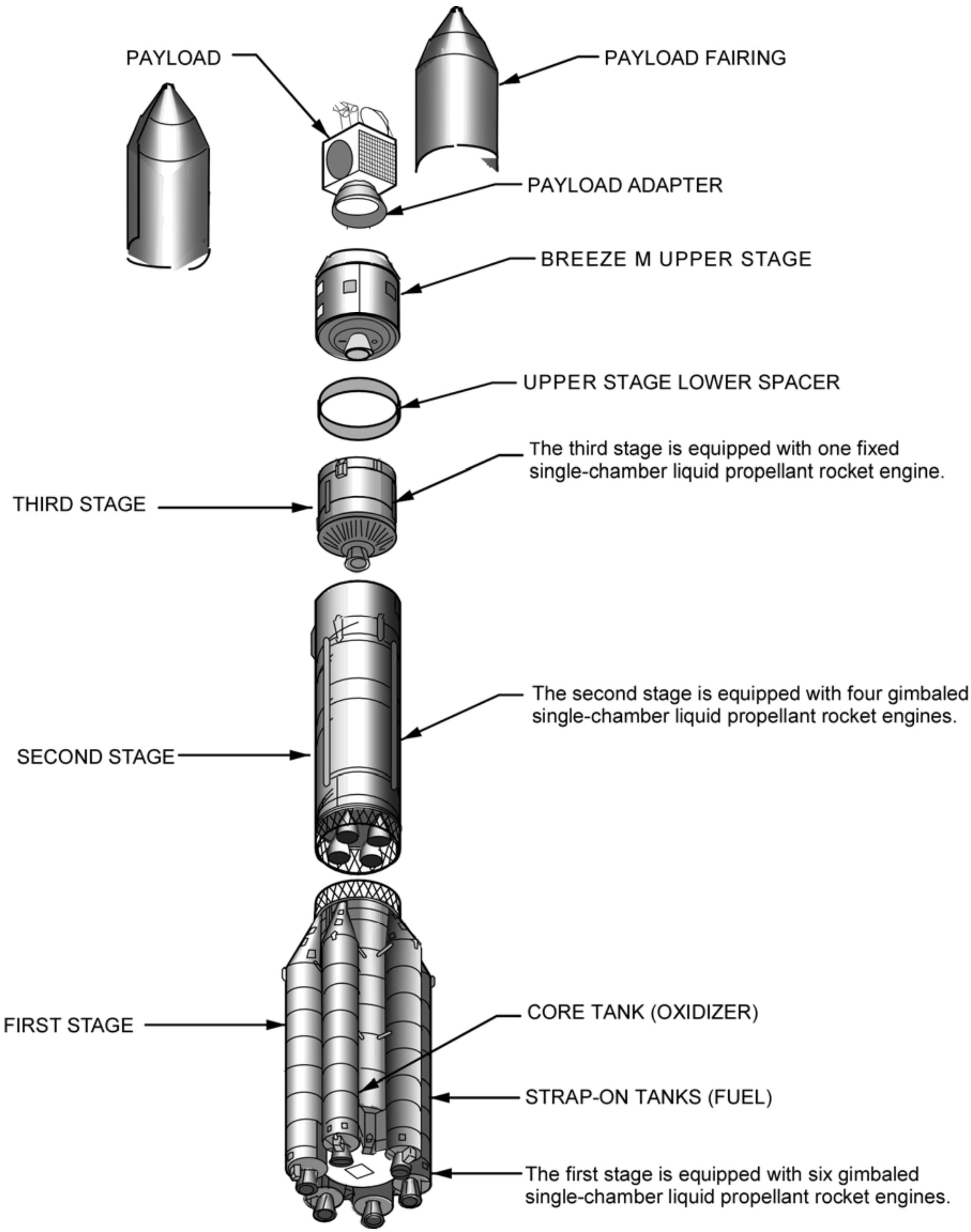


Figure A.3-2: General Layout of Breeze M with Auxiliary Propellant Tank

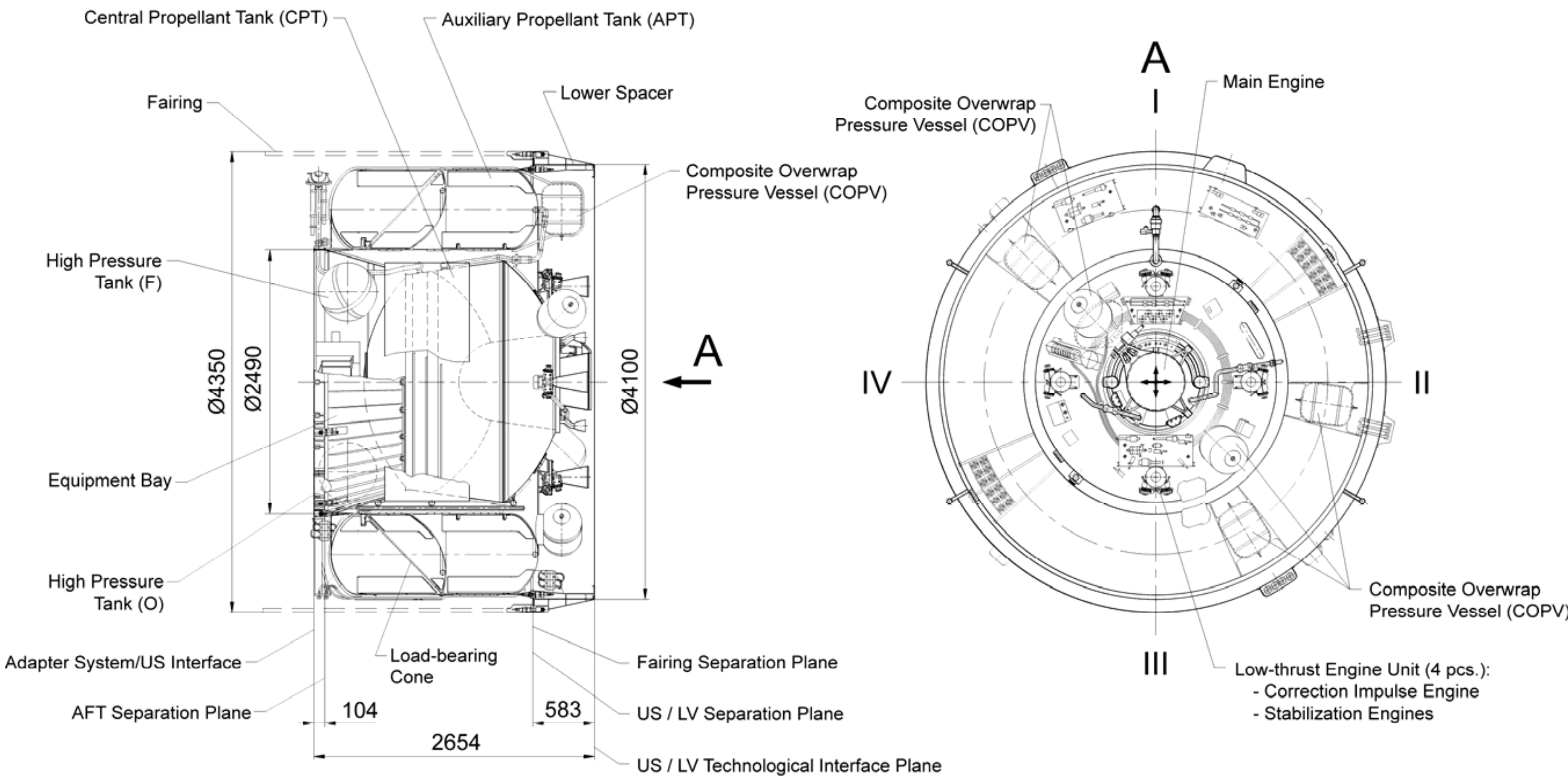
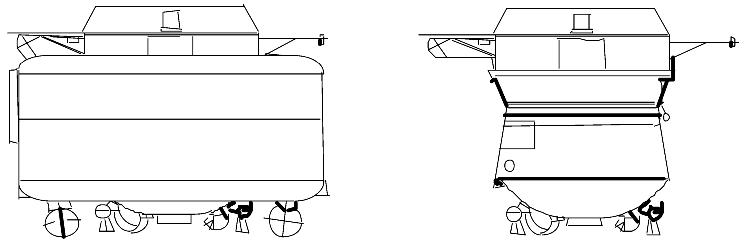


Figure A.3-3: Breeze M in Flight with and without Auxiliary Propellant Tank



A.3.1 Central Block

The central block consists of the Central Propellant Tank (CPT) with the propulsion system and the equipment bay, in which the on-board avionics systems are installed.

The CPT comprises the oxidizer and fuel tanks, which are separated by an intermediate bulkhead; the oxidizer tank is positioned on top, and the fuel tank below. The 14D30 main propulsion engine is a gimbaled storable propellant design, secured in the interior niche of the tanks. Inside the tanks are elements of the pneumatic and hydraulic system, as well as baffles to dampen propellant sloshing. The lower dome has mounted on it four low-thrust settling/attitude control thruster units (each consisting of one 11D458M settling/impulse adjustment thruster and three 17D58E attitude control thrusters), Composite Overwrapped Pressure Vessels (COPV) containing helium for pressurization of the central block, and other elements of the pneumatic and hydraulic system. A hinged rotating heat-protective cover is secured to the exterior of the lower dome to maintain the required temperature regime in the main propulsion engine in intervals between operations. The lines of the apparatus compartment thermal mode support (thermal control) system are mounted on the conical shell of the center propellant tank.

The unpressurized equipment bay is implemented as an inverted truncated cone and is secured to the top frame of the CPT. Inside the compartment is the primary structural subframe, on which are installed the electronic equipment boxes of various Breeze M systems and the on-board power sources. The adapter system for mounting the SC is secured to the top frame of the hardware compartment.

The Breeze M core structure provides the payload adapter (PLA) and electrical interfaces to the Customer's SC. The interface between the Breeze M and the PLA is 2490 mm in diameter, allowing the Breeze M to accommodate large diameter payload adapters. The payload structural load limits are discussed in Section 4.1.2. The Breeze M stage is encapsulated within the payload fairing (PLF), along with the Customer's SC, allowing loads from the PLF to be borne by the Breeze M lower spacer (583 mm).

A.3.2 Auxiliary Propellant Tank

The Auxiliary Propellant Tank (APT) is positioned around the central block and is implemented as a toroidal compartment with cylindrical shells and an intermediate bulkhead that divides the compartment into the oxidizer tank (top) and fuel tank (bottom). Loads are conveyed from the SC and central block through the load-bearing cone inside the oxidizer tank and through the outer cylindrical shell of the fuel tank. The cone has been optimized to increase the load bearing capability and reduce quasi-static loads on the spacecraft. Loads are then transferred to the bottom spacer of the Breeze M. Inside the tanks are elements of the pneumatic and hydraulic system, as well as baffles to damp propellant sloshing. On the exterior of the lower dome of the APT are elements of the pneumatic and hydraulic system, including bottles for pressurization of the APT, units of automatic pneumatic and hydraulic equipment, and boards with electrical connectors.

When the APT is jettisoned, the pyrotechnic locks that connect the tank to the central block are fired, and electrical and hydraulic connections are broken. Then a set of spring pushers are actuated, and the APT is separated from the central block by means of two guides on the APT and roller supports on the central block.

A.3.3 Propulsion System

The Breeze M uses nitrogen tetroxide (N_2O_4) and unsymmetrical-dimethylhydrazine (UDMH) as propellants. Propulsion for the Breeze M consists of one pump-fed, gimbaled 14D30 main engine developing 19.62 kN (4411 lbf) thrust, four 11D458M settling/impulse adjustment thrusters with 392 N (88 lbf) thrust for making fine trim maneuver corrections to the main engine impulse, and twelve 17D58E attitude control thrusters with 13.3 N (3.0 lbf) thrust each. The main engine can fire up to eight times per mission, and is equipped with a backup restart system that can fire the engine in the event of a primary ignition sequence failure. The main engine can be commanded to shut down either upon achieving a desired state vector or propellant depletion.

The propulsion system of the Breeze M is derived from, and has a high degree of commonality with, previous flight systems. During two flights of the Phobos space probes in 1988 and three flights of the Breeze K on the Rokot in 1990, 1991, and 1994 the main engine demonstrated up to five restarts in flight. Following minor modifications to adapt the engine for the Breeze M, 11 main engines were ground tested — some up to 6,000 seconds total burn duration. The Breeze M attitude control thrusters were previously used on the Kvant, Kristall, Spektr, and Priroda modules of the MIR space station, and are used on the Russian FGB Zarya and Service Module Zvezda components of the International Space Station. As of 31 July 2009, the Breeze M propulsion system has operated successfully on 30 flights, performing multiple burns on each mission.

The propulsion system of the Breeze M performs the following actions:

– Provides thrust pulses specified in the flight program to trim velocity.
– Controls the angular motion of the stage.
– Performs repeated firings of the main propulsion engine under weightless conditions.
– Supplies propellant from the tanks to the engines.
– Pressurizes the propellant tanks.

Characteristics of the engines used in the Breeze M propulsion system are provided in Table A.3.3-1.

Table A.3.3-1: Basic Characteristics of the Breeze M Propulsion System

Main Propulsion Engine	
Designation	14D30
Vacuum Thrust	19.62 kN
Number of Firings Per Flight	Up to 8
Thrusters	
Vernier Engines:	
Designation	11D458M
Number of	4
Vacuum Thrust	392 N
Attitude and Stabilization Engines:	
Designation	17D58E
Number of	12
Vacuum Thrust	13.3 N

A.3.4 Control System and Telemetry System

The control system of the Breeze M includes a three-channel voting on-board digital computer, precision three-axis gyro stabilized platform, and navigation systems. The following functions are performed by the control system.

- Inertial navigation
- Terminal guidance
- Attitude control
- Control of the operating modes of the propulsion system and other Breeze M on-board systems
- Information exchange with the SC and LV control systems
- Control of separation of the APT and SC
- Electrical power supply to Breeze M on-board equipment

The Breeze M can perform preprogrammed maneuvers about all axes during parking, intermediate, and transfer orbit coasts. The Breeze M is normally three-axis stabilized during coast. During powered flight, the Breeze M attitude is determined by navigational algorithms of the flight control system. The Breeze M attitude can be controlled in coasting mode to an angular pointing accuracy of ± 10.0 degrees in coarse pointing mode and ± 1.0 degree in fine pointing mode. When the Breeze M is coasting in rotation mode, angular velocity accuracy is ± 0.5 deg/s.

Thermal control of the SC can be provided through the use of a control maneuver, in which the Breeze M and SC rotate about the longitudinal X or transverse Z axis of the Breeze M. Maneuvers of 180 degrees performed in one direction (lasting no more than 600 seconds about the longitudinal axis) or 900 seconds about the transverse axis, can be used. Alternatively, continuous rotation of the Breeze M is possible about the longitudinal axis, with an angular velocity of up to 3 deg/s.

The possibility of performing these maneuvers, as well as continuous rotation, will be defined by the SC sun exposure and launch window requirements.

Breeze M can perform separation of a Customer's SC in any one of three modes, depending upon SC separation requirements and launch window:

1) Three-axis stabilization mode, during which the separation-induced SC angular rates in relation to any of the three coordinate system axes will not exceed 1.0 deg/s, and the spatial attitude error in relation to the inertial coordinate system will not exceed ± 5 degrees, or

2) Longitudinal spin-up mode, during which the Breeze M can achieve a maximum angular rate of 6.0 deg/s about its longitudinal axis, and the SC spin axis deviation from the Breeze M longitudinal axis after separation will not exceed ± 5 degrees, and will be determined by the SC characteristics and Customer requirements for SC separation dynamics, or

3) Transverse spin-up mode, in which the SC is spun around the transverse axis either by use of unsymmetrical springs or by rotation of the Breeze M at an angular velocity of up to 2.0 deg/s.

The Breeze M telemetry system (on-board measuring complex) performs the following functions:

- Collection of data on the state of design elements and on the operation of the Breeze M and SC systems and units (according to an agreed upon list) throughout all stages of flight and during pre-launch preparations.

- Transmission of telemetry data to ground measuring stations.

All equipment in the on-board measuring complex was especially developed for the Breeze M.

The telemetry data acquisition system operates in direct transmission mode, memory mode, playback mode, or the combined modes, executing programs that differ in telemetered parameters and polling frequencies.

Radio frequency measurements are recorded by means of the Breeze M telemetry system. The Breeze M can make use of both the GLONASS and GPS satellite navigation systems.

The parameters monitored by the telemetry system are summarized below:

- During processing, launch and flight, the operation of Breeze M systems and components is under constant monitoring by the telemetry measurement system and the control system.

- The load on and state of the Breeze M structure are monitored for 120 parameters.

- The operation of the propulsion unit is monitored for 83 parameters.

- The operation of the thermal mode support system is monitored for 20 parameters.

- The operation of the control system is monitored for more than 200 parameters.

The data obtained, in the form of files of analog and digital parameters, are sent to ground measuring stations and put through comprehensive analysis.

A.3.5 Thermal Control System

The thermal control system (thermal mode support system) is a complex of means of active and passive temperature regulation that includes the following elements:

- The thermal control system, which maintains the specific temperature of the Breeze M elements and radiates excess heat into space by means of the control system. The thermal control system consists of a hydraulic circuit, which includes a radiative heat exchanger, an electrical pump unit, a switch, cold plates (heat sinks), heat pipes of the instrument subframe, and the coils of the instrument subframe and propellant compartment.

- Means of passive temperature regulation, which handle external heat exchange of the Breeze M within the range determined by heat losses and heat influxes, as well as the thermal conditions of units by means of temperature-regulating coatings, thermostats, thermal resistances, and vacuum thermal insulation (Multi-Layer Insulation, MLI).

A.4 PROTON FLIGHT HISTORY SUMMARY

The total number of operational missions flown by Proton three and four-stage configurations since the first Proton launch is 323 as of 31 July 2009. If development flights are included, then the Proton has flown in excess of 340 times. It has launched the Ekran, Raduga, and Gorizont series of geostationary communications satellites (which provided telephone, telegraph, and television service within Russia and between member states of the Intersputnik Organization), as well as the Zond, Luna, Venera, Mars, Vega, and Phobos inter-planetary exploration SC. All Russian unmanned lunar landing missions were flown by Proton. The Proton has also launched the entire constellation of Glonass position location satellites and has carried the Salyut series space stations and the Mir space station modules. Proton launched the Zarya and Zvezda modules, which comprised the first two elements of the International Space Station. All Russian geostationary and interplanetary missions are launched on Proton. Approximately 90% of all Proton launches have been of a four-stage version.

As of 31 July 2009, ILS has launched 52 commercial SC on Proton.

The Proton LV is one of the most reliable commercial launch vehicles available today. Summary launch data by year are shown in Table A.4-2.

Table A.4-1: Breeze M Flight History

Breeze M Flight Number	Launch Date (GMT)	Mission Name	Mission Type	Payload Separated Mass (kg)	Launch Pad	Approximate Mission Duration (hrs)	Number of Breeze M Burns	Hardware - Main Stages, Adapter, PLF	Results
1	5 July 1999	Raduga	GSO	1932	24	-	-	LV: Proton K PLF: 14C75 Adapter H = 465 mm (metal)	Proton second stage failure; no trial
2	6 June 2000	Gorizont	GSO	2158	24	9.2	4	LV: Proton K PLF: 14C75 Adapter H = 465 mm (metal)	Successful
3	7 Apr 2001	Ekran M	GSO	2005	24	6.8	3	LV: Proton M PLF: 14C75 Adapter H = 465 mm (metal)	Successful
4	30 Dec 2002	NIMIQ 2	GTO	3600	24	6.9	4	LV: Proton M PLF: MITS Adapter H = 1000 mm (carbon fiber)	Successful
5	7 Jun 2003	AMC-9	GTO	4100	39	8.9	5	LV: Proton K PLF: 14C75 Adapter H = 1000 mm (carbon fiber)	Successful
6	10 Dec 2003	GLONASS	MEO	4110 (3 x 1370)	24	5.8	3	LV: Proton K PLF: 14C75 Adapter H = 465 mm (metal)	Successful
7	16 Mar 2004	W3A	GTO	4200	24	9.2	5	LV: Proton M PLF: 14C75 Adapter H = 1000 mm (carbon fiber)	Successful
8	17 Jun 2004	Intelsat 10-02	GTO	5575	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
9	5 Aug 2004	Amazonas 1	GTO	4540	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
10	14 Oct 2004	AMC 15	GTO	4021	39	6.9	3	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful

Table A.4-1: Breeze M Flight History (Continued)

Breeze M Flight Number	Launch Date (GMT)	Mission Name	Mission Type	Payload Separated Mass (kg)	Launch Pad	Approximate Mission Duration (hrs)	Number of Breeze M Burns	Hardware - Main Stages, Adapter, PLF	Results
11	3 Feb 2005	AMC-12	GTO	4974	24	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
12	22 May 2005	DirecTV 8	GTO	3709	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
13	9 Sep 2005	Anik F1R	GTO	4471	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
14	29 Dec 2005	AMC-23	GTO	4981	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
15	28 Feb 2006	Arabsat-4A	GTO	3341	39	4.0	4	LV: Proton M PLF: PLF-BR-11600 Adapter H = 1168 mm (carbon fiber)	Failure
16	4 Aug 2006	Hot Bird 8	GTO	4910	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
17	8 Nov 2006	Arabsat-4B	GTO	3304	39	4.0	4	LV: Proton M PLF: PLF-BR-11600 Adapter H = 1168 mm (carbon fiber)	Successful
18	11 Dec 2006	Measat 3	GTO	4757	39	9.2	5	LV: Proton M PLF: PLF-BR-13305 Adapter H = 1000 mm (metal)	Successful
19	9 Apr 2007	Anik F3	GTO	4639	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
20	7 Jul 2007	DirecTV 10	GTO	5893	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful

Table A.4-1: Breeze M Flight History (Continued)

Breeze M Flight Number	Launch Date (GMT)	Mission Name	Mission Type	Payload Separated Mass (kg)	Launch Pad	Approximate Mission Duration (hrs)	Number of Breeze M Burns	Hardware - Main Stages, Adapter, PLF	Results
21	5 Sep 2007	JCSat-11	GTO	4004	39	7.0	4	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Failure
22	17 Nov 2007	SIRIUS 4	GTO	4392	39	9.2	4	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
23	9 Dec 2007	Cosmos-2434	GSO	TBD	TBD	9.0	4	LV: Proton M PLF: PLF-BR-11600 Adapter H = 465 mm (metal)	Successful
24	28 Jan 2008	Express AM-33	GSO	TBD	TBD	9.0	4	LV: Proton M PLF: PLF-BR-13305 Adapter H = 465 mm (metal)	Successful
25	10 Feb 2008	Thor 5	GSO	1939	39	9.2	4	LV: Proton M PLF: PLF-BR-11600 Adapter H = 1168 mm (carbon fiber)	Successful
26	14 Mar 2008	AMC-14	GTO	4149	39	7.0	3	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Failure
27	18 Aug 2008	Inmarsat 4F3	GTO	5956	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
28	19 Sep 2008	Nimiq 4	GTO	4839	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
29	5 Nov 2008	Astra-1M	GTO	5320	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful

Table A.4-1: Breeze M Flight History (Continued)

Breeze M Flight Number	Launch Date (GMT)	Mission Name	Mission Type	Payload Separated Mass (kg)	Launch Pad	Approximate Mission Duration (hrs)	Number of Breeze M Burns	Hardware - Main Stages, Adapter, PLF	Results
30	10 Dec 08	Ciel-2	GTO	5588	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
31	11 Feb 09	Express-AM44/ Express MD1	GSO	3672	39	9.0	4	LV: Proton M PLF: PLF-BR-15255	Successful
32	3 April 09	W2A	GTO	5918	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful
33	16 May 09	ProtoStar II	GTO	4007	39	9,2	5	LV: Proton M PLF: PLF-BR-13305 Adapter H = 1000 mm (metal)	Successful
34	30 June 2009	Sirius FM-5	GTO	5820	39	9.2	5	LV: Proton M PLF: PLF-BR-15255 Adapter H = 1000 mm (carbon fiber)	Successful

Table A.4-2: Proton Operational Launch Record Summary (1970 - 2009)

Year	Number of Launches	Number of Launches by Version		Total Launches on Accrual Basis	Failures	
		4-Stage Version	3-Stage Version		Type of Vehicle	Cause (Details in Section A.6)
1970	6	5	1	6	1 Proton K Block DM	a
1971	6	5	1	12		
1972	2	1	1	14	1 Proton K	b
1973	7	5	2	21		
1974	6	4	2	27		
1975	5	5	-	32	1 Proton K Block DM	c
1976	5	3	2	37		
1977	5	2	3	42	1 Proton K	d
1978	8	7	1	50	3 Proton K Block DM	e, f, g
1979	6	5	1	56		
1980	5	5	-	61		
1981	7	6	1	68		
1982	10	9	1	78	2 Proton K Block DM	h, i
1983	12	11	1	90		
1984	13	13	-	103		
1985	10	9	1	113		
1986	9	7	2	122	1 Proton K	j
1987	13	11	2	135	2 Proton K Block DM	k, l
1988	13	13	-	148	2 Proton K Block DM	m, n
1989	11	10	1	159		
1990	11	10	1	170	1 Proton K Block DM	o
1991	9	8	1	179		
1992	8	8	-	187		
1993	6	6	-	193	1 Proton K Block DM	p
1994	13	13	-	206		
1995	7	6	1	213		
1996	8	7	1	221	2 Proton K Block DM	q, r
1997	9	9	-	230	1 Proton K Block DM	s
1998	7	6	1	237		
1999	9	9	-	246	2 Proton K Block DM	t, u
2000	14	13	1	260		
2001	6	6	-	266		
2002	9	9	-	275	1 Proton K Block DM	v
2003	5	5	-	280		
2004	7	7	-	288		
2005	7	7	-	295		
2006	6	6	-	301	1 Proton M/Breeze M	w
2007	7	7	-	308	1 Proton M/Breeze M	x
2008	8	10	-	318	1 Proton M/Breeze M	y
2009	5	5	-	323		

Note: As of 31 July 2009

A.5 DETAILED PROTON FLIGHT HISTORY

The Proton launch history since 1970 is shown in Table A.5-1. The stated orbital parameters are approximate and included for information only.

Table A.5-1: Proton Operational Launch History

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
1	6 Feb 1970	√		Cosmos	Failed to orbit	Command abort
2	18 Aug 1970		√	Experimental	Ballistic Test	
3	12 Sep 1970	√		Luna-16	Escape	
4	20 Oct 1970	√		Zond-8	Escape	
5	10 Nov 1970	√		Luna-17	Escape	
6	2 Dec 1970		√	Cosmos-382	2464 km x 5189 km at 51.9 deg	
7	19 Apr 1971		√	Salyut-1	200 km x 210 km at 51.6 deg	
8	10 May 1971	√		Cosmos-419	145 km x 159 km at 51.5 deg	
9	19 May 1971	√		Mars-2	Escape	
10	28 May 1971	√		Mars-3	Escape	
11	2 Sep 1971	√		Luna-18	Escape	
12	28 Sep 1971	√		Luna-19	Escape	
13	14 Feb 1972	√		Luna-20	Escape	
14	29 Jul 1972		√	Salyut	Failed to orbit	
15	8 Jan 1973	√		Luna-21	Escape	
16	3 Apr 1973		√	Salyut-2	207 km x 248 km at 51.6 deg	
17	11 May 1973		√	Cosmos-557	214 km x 243 km at 51.6 deg	
18	21 Jul 1973	√		Mars-4	Escape	
19	25 Jul 1973	√		Mars-5	Escape	
20	5 Aug 1973	√		Mars-6	Escape	
21	9 Aug 1973	√		Mars-7	Escape	
22	26 Mar 1974	√		Cosmos-637	LEO	
23	29 May 1974	√		Luna-22	Escape	
24	24 Jun 1974		√	Salyut-3	LEO	
25	29 Jul 1974	√		Molniya-1S	Elliptical orbit	
26	28 Oct 1974	√		Luna-23	Escape	
27	26 Dec 1974		√	Salyut-4	LEO	
28	6 Jun 1975	√		Venera-9	Earth escape	
29	14 Jun 1975	√		Venera-10	Earth escape	
30	8 Oct 1975	√		Cosmos-775	LEO	

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
31	16 Oct 1975	√		Luna	Escape	
32	22 Dec 1975	√		Raduga-1	GSO	
33	22 Jun 1976		√	Salyut-5	LEO	
34	9 Aug 1976	√		Luna-24	Escape	
35	11 Sep 1976	√		Raduga-2	GSO	
36	26 Oct 1976	√		Ekran-1	GSO	
37	15 Dec 1976		√	Cosmos-881 and 882	LEO	
38	17 Jul 1977	√		Cosmos-929	301 km x 308 km at 51.5 deg	
39	23 Jul 1977	√		Raduga-3	GSO	
40	05 Aug 1977		F	Cosmos	Failed to orbit	
41	20 Sep 1977	√		Ekran-2	GSO	
42	29 Sep 1977		√	Salyut-6	380 km x 391 km at 51.6 deg	
43	30 Mar 1978		√	Cosmos-997 and 998	230 km x 200 km at 51.6 deg	
44	27 May 1978	F		Ekran	Failed to orbit	First stage failure
45	18 Jul 1978	√		Raduga-4	GSO	
46	17 Aug 1978	F		Ekran	Failed to orbit	Second stage failure
47	9 Sep 1978	√		Venera-l l	Escape	
48	14 Sep 1978	√		Venera-12	Escape	
49	17 Oct 1978	F		Ekran	Failed to orbit	Second stage failure
50	19 Dec 1978	√		Gorizont-1	20,600 km x 50,960 km at 14.3 deg	Block DM failure
51	21 Feb 1979	√		Ekran-3	GSO	
52	25 Apr 1979	√		Raduga-5	GSO	
53	22 May 1979		√	Cosmos-1100 and 1101	193 km x 223 km at 51.6 deg	
54	5 Jul 1979	√		Gorizont-2	GSO	
55	3 Oct 1979	√		Ekran-4	GSO	
56	28 Dec 1979	√		Gorizont-3	GSO	
57	2 Feb 1980	√		Raduga-6	GSO	
58	14 Jun 1980	√		Gorizont-4	GSO	
59	15 Jul 1980	√		Ekran-5	GSO	
60	5 Oct 1980	√		Raduga-7	GSO	
61	26 Dec 1980	√		Ekran-6	GSO	
62	18 Mar 1981	√		Raduga-8	GSO	
63	25 Apr 1981		√	Cosmos-1267	240 km x 278 km at 51.5 deg	
64	26 Jun 1981	√		Ekran-7	GSO	
65	30 Jul 1981	√		Raduga-9	GSO	
66	9 Oct 1981	√		Raduga-10	GSO	
67	30 Oct 1981	√		Venera-13	Escape	
68	4 Nov 1981	√		Venera-14	Escape	

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
69	5 Feb 1982	√		Ekran-8	GSO	
70	15 Mar 1982	√		Gorizont-5	GSO	
71	19 Apr 1982		√	Salyut-7	473 km x 474 km at 51.6 deg	
72	17 May 1982	√		Cosmos-1366	GSO	
73	23 Jul 1982	F		Ekran	Failed to orbit	First stage failure
74	16 Sep 1982	√		Ekran-9	GSO	
75	12 Oct 1982	√		Cosmos-1413 and 1415	19,000 km x 19,000 km at 64.7 deg	
76	20 Oct 1982			Gorizont-6	GSO	
77	26 Nov 1982	√		Raduga-11	GSO	
78	24 Dec 1982	F		Raduga	Failed to orbit	Second stage failure
79	2 Mar 1983	√		Cosmos-1443	324 km x 327 km at 51.6 deg	
80	12 Mar 1983	√		Ekran-10	GSO	
81	23 Mar 1983	√		Astron-1	1,950 km x 201,100 km at 51.09 deg	
82	8 Apr 1983		√	Raduga-12	GSO	
83	2 Jun 1983	√		Venera-15	Escape	
84	6 Jun 1983	√		Venera-16	Escape	
85	1 Jul 1983	√		Gorizont-7	GSO	
86	10 Aug 1983	√		Cosmos-1490 and 1492	19,000 km x 19,000 km at 64.8 deg	
87	25 Aug 1983	√		Raduga-13	GSO	
88	29 Sep 1983	√		Ekran-II	GSO	
89	30 Nov 1983	√		Gorizont-8	GSO	
90	29 Dec 1983	√		Cosmos-1519 and 1521	19,000 km x 19,000 km at 64.8 deg	
91	15 Feb 1984	√		Raduga-14	GSO	
92	2 Mar 1984	√		Cosmos-1540	GSO	
93	16 Mar 1984	√		Ekran-12	GSO	
94	29 Mar 1984	√		Cosmos-1546	GSO	
95	22 Apr 1984	√		Gorizont-9	GSO	
96	19 May 1984	√		Cosmos-1554 and 1556	19,000 km x 19,000 km at 64.8 °	
97	22 Jun 1984	√		Raduga-15	GSO	
98	1 Aug 1984	√		Gorizont-10	GSO	
99	24 Aug 1984	√		Ekran-13	GSO	
100	4 Sep 1984	√		Cosmos-1593 and 1595	19,000 km x 19,000 km at 64.8 °	
101	28 Sep 1984	√		Cosmos-1603	836 km x 864 km at 71 deg	
102	15 Dec 1984	√		Vega-1	Escape	
103	21 Dec 1984	√		Vega-2	Escape	
104	18 Jan 1985	√		Gorizont-ll	GSO	
105	21 Feb 1985	√		Cosmos-1629	GSO	
106	22 Mar 1985	√		Ekran-14	GSO	
107	17 May 1985	√		Cosmos-1650 and 1652	19,000 km x 19,000 km at 64.8 °	
108	30 May 1985	√		Cosmos-1656	800 km x 860 km at 71.1 deg	
109	8 Aug 1985	√		Raduga-16	GSO	
110	27 Sep 1985		√	Cosmos-1686	291 km x 312 km at 51.6 deg	

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
111	25 Oct 1985	√		Cosmos-1700	GSO	
112	15 Nov 1985	√		Raduga-17	GSO	
113	24 Dec 1985	√		Cosmos-1710 and 1712	19,000 km x 19,000 km at 64.8 deg	
114	17 Jan 1986	√		Raduga-18	GSO	
115	19 Feb 1986		√	Mir	335 km x 358 km at 51.6 deg	
116	4 Apr 1986	√		Cosmos-1738	GSO	
117	24 May 1986	√		Ekran-15	GSO	
118	10 Jun 1986	√		Gorizont-12	GSO	
119	16 Sep 1986	√		Cosmos-1778 and 1780	19,000 km x 19,000 km at 64.8 deg	
120	25 Oct 1986	√		Raduga-I9	GSO	
121	18 Nov 1986	√		Gorizont-13	GSO	
122	29 Nov 1986		F	Almaz	Failed to orbit	Second stage failure
123	30 Jan 1987	F		Cosmos-1817	192 km x 224 km at 51.6 deg	Fourth stage control system failure
124	31 Mar 1987		√	Kvant-1	298 km x 344 km at 51.6 deg	
125	19 Apr 1987	√		Raduga-20	GSO	
126	24 Apr 1987	F		Cosmos- 1838 to 1840	200 km x 17,000 km at 64.9 deg	Fourth stage early shutdown
127	11 May 1987	√		Gorizont-14	GSO	
128	25 Jul 1987		√	Cosmos-1870	237 km x 249 km at 71.9 deg	
129	3 Sep 1987	√		Ekran-16	GSO	
130	16 Sep 1987	√		Cosmos-1883 and 1885	19,000 km x 19,000 km at 64.8 deg	
131	1 Oct 1987	√		Cosmos-1888	GSO	
132	28 Oct 1987	√		Cosmos-1894	GSO	
133	26 Nov 1987	√		Cosmos-1897	GSO	
134	10 Dec 1987	√		Raduga-21	GSO	
135	27 Dec 1987	√		Ekran-17	GSO	
136	18 Jan 1988	F		Gorizont	Failed to orbit	Third stage failure
137	17 Feb 1988	F		Cosmos-1917P1919	162 km x 170 km at 64.8 deg	Fourth stage did not ignite
138	31 Mar 1988	√		Gorizont-15	GSO	
139	26 Apr 1988	√		Cosmos-1940	GSO	
140	6 May 1988	√		Ekran-18	GSO	
141	21 May 1988	√		Cosmos 1946-1948	19,000 km x19,000 km at 64.9 deg	
142	7 Jul 1988	√		Phobos-1	Escape	
143	12 Jul 1988	√		Phobos-2	Escape	
144	1 Aug 1988	√		Cosmos-1961	GSO	
145	18 Aug 1988	√		Gorizont-16	GSO	
146	16 Sep 1988	√		Cosmos-1970P1972	19,000 km x 19,000 km at 64.8 deg	
147	20 Oct 1988	√		Raduga-22	GSO	
148	10 Dec 1988	√		Ekran-I9	GSO	

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
149	10 Jan 1989	√		Cosmos-1987P1989	19,000 km x 19,000 km at 64.9 deg	
150	26 Jan 1989	√		Gorizont-17	GSO	
151	14 Apr 1989	√		Raduga-23	GSO	
152	31 May 1989	√		Cosmos-2022P2024	19,000 km x 19,000 km at 64.8 deg	
153	21 Jun 1989	√		Raduga-l-1	GSO	
154	5 Jul 1989	√		Gorizont-18	GSO	
155	28 Sep 1989	√		Gorizont-19	GSO	
156	26 Nov 1989		√	Kvant-2	215 km x 321 km at 51.6 deg	
157	1 Dec 1989	√		Granat	1957 km x 201,700 km at 52.1 deg	
158	15 Dec 1989			Raduga-24	GSO	
159	27 Dec 1989	√		Cosmos-2054	Unknown	
160	15 Feb 1990	√		Raduga-25	GSO	
161	19 May 1990	√		Cosmos-2079P81	19,000 km x19,000 km at 65 deg	
162	31 May 1990		√	Kristall	383 km x 481 km at 51.6 deg	
163	20Jun 1990	√		Gorizont-20	GSO	
164	18 Jul 1990	√		Cosmos-2085	GSO	
165	9 Aug 1990	F		Unknown	Did not achieve orbit	
166	3 Nov 1990	√		Gorizont-21	GSO	
167	23 Nov 1990	√		Gorizont-22	GSO	
168	8 Dec 1990	√		Cosmos-2109P11	19,000 km x 19,000 km at 64.8 deg	
169	20 Dec 1990	√		Raduga-26	GSO	
170	27 Dec 1990	√		Raduga-26	GSO	
171	14 Feb 1991	√		Cosmos-2133	GSO	
172	28 Feb 1991	√		Raduga-27	GSO	
173	31 Mar 1991		√	Almaz-1	268 km x 281 km at 72.7 deg	
174	4 Apr 1991	√		Cosmos-2139P41	19,000 km x 19,000 km at 64.9 deg	
175	1 Jul 1991	√		Gorizont-23	GSO	
176	13 Sep 1991	√		Cosmos-2155	GSO	
177	23 Oct 1991	√		Gorizont-24	GSO	
178	22 Nov 1991	√		Cosmos-2172	GSO	
179	19 Dec 1991	√		Raduga-28	GSO	
180	29 Jan 1992	√		Cosmos-2177P79	19,000 km x 19,000 km at 64.8 deg	
181	2 Apr 1992	√		Gorizon-25	GSO	
182	14Ju11992	√		Gorizont-26	GSO	
183	30 Jul 1992	√		Cosmos-2204-06	19,000 km x 19,000 km at 64.8 deg	
184	10 Sep 1992	√		Cosmos-2209	GSO	
185	30 Oct 1992	√		Ekran-20	GSO	
186	27Nov 1992	√		Gorizont-27	GSO	
187	17 Dec 1992	√		Cosmos-2224	GSO	
188	17 Feb 1993	√		Cosmos-223?P3?	19,000 km x 19,000 km at 64.8 deg	
189	17 Mar 1993	√		Raduga-29	GSO	
190	27 May 1993	F		Gorizont	Did not achieve orbit	$2^{nd}/3^{rd}$ stage propulsion failure
191	30 Sep 1993	√		Gorizont	GSO	
192	28 Oct 1993	√		Gorizont	GSO	
193	18 Nov 1993	√		Gorizont	GSO	

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
194	20 Jan 1994	√		GALS	GSO	
195	5 Feb 1994	√		Raduga-30	GSO	
196	18 Feb 1994	√		Raduga-31	GSO	
197	11 Apr 1994	√		Glonass	19,000 km x 19,000 km at 64.8°	
198	20 May 1994	√		Gorizant	GSO	
199	7 Jul 1994	√		Cosmos	GSO	
200	11 Aug 1994	√		Glonass	19,000 km x 19,000 km at 64.8°	
201	21 Sep 1994	√		Cosmos-2291	GSO	
202	13 Oct 1994	√		Express	GSO	
203	31 Oct 1994	√		Electro	GSO	
204	20 Nov 1994	√		Glonass	19,000 km x 19,999 km at 64.8°	
205	16 Dec 1994	√		Luch	GSO	
206	28 Dec 1994	√		F Raduga-32	GSO	
207	7 Mar 1995	√		Glonass	19,000 km x 19,000 km at 64.8°	
208	20 May 1995		√	Spektr	335 km x 358 km at 51.6°	
209	24 Jul 1995	√		Glonass	19,000 km x 19,000 km at 64.8°	
210	31 Aug 1995	√		Gazer	GSO	
211	11 Oct 1995	√		Looch-1	GSO	
212	17 Nov 1995	√		GALS	GSO	
213	14 Dec l995	√		F Glonass	19,140 km x 19,100 km at 64.8°	
214	25 Jan 1996	√		Gorizant	GSO	
215	19 Feb 1996	F		Raduga	GSO	Block DM propulsion failure
216	9 Apr 1996	√		Astra 1F	GTO	Commercial
217	23 Apr 1996		√	Priroda	214 km x 328 km at 51.6 deg	
218	25 May 1996	√		Gorizant	GSO	
219	6 Sep 1996	√		Inmarsat 3 F2	GSO	Commercial
220	26 Sep 1996	√		Express	GSO	
221	16 Nov 1996	F		Mars 96	Did not achieve escape trajectory	Failure of Mars 96 control system to initiate Block D2 engine ignition
222	24 May 1997	√		Telstar-5	GTO	Commercial
223	6 June 1997	√		Arak	GSO	
224	18 June 1997	√		Iridium	LEO	Commercial
225	14 Aug 1997	√		Cosmos-2345	GSO	
226	28 Aug 1997	√		PanAmSat-5	GTO	Commercial
227	15 Sep 1997	√		Iridium	LEO	Commercial
228	12 Nov 1997	√		Kupon	GSO	
229	3 Dec 1997	√		Astra-1G	GTO	Commercial
230	25 Dec 1997	F		AsiaSat-3	GTO	Block DM engine failure
231	7 Apr 1998	√		Iridium	LEO	Commercial
232	29 Apr 1998	√		Cosmos-2350	GSO	
233	8 May 1998	√		Echostar-IV	GTO	Commercial
234	30 Aug 1998	√		Astra 2A	GTO	Commercial

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
235	04 Nov 1998	√		PanAmSat-8	GTO	Commercial
236	20 Nov 1998		√	Zarya (FGB)	LEO	RSA/NASA
237	30 Dec 1998	√		Glonass	MEO	
238	15 Feb 1999	√		Telstar 6	GTO	Commercial
239	28 Feb 1999	√		Globus 1	GSO	
240	21 Mar 1999	√		Asiasat 3S	GTO	Commercial
241	21 May 1999	√		NIMIQ 1	GTO	Commercial
242	18 June 1999	√		Astra 1H	GTO	Commercial
243	5 July 1999	√		Raduga	GSO	Second stage sustainer failure, Proton K Breeze M first flight
244	6 Sep 1999	√		Yamal 101-102	GSO	
245	27 Sep 1999	√		LMI-1	GTO	Commercial
246	27 Oct 1999	√		Express A1	GSO	Second stage sustainer failure
247	12 Feb 2000	√		Garuda-1 (ACeS)	GTO	Commercial
248	12 Mar 2000	√		Express 6-A	GSO	
249	18 Apr 2000	√		Sesat	GSO	
250	6 June 2000	√		Gorizont 45	GSO	Proton K Breeze M 2nd flight
251	24 June 2000	√		Express 3-A	GSO	
252	1 July 2000	√		Sirius-1	HEO	Commercial
253	5 July 2000	√		Geyser	GSO	
254	12 July 2000		√	Zvezda-ISS	LEO	
255	29 Aug 2000	√		Globus	GTO	
256	5 Sep 2000	√		Sirius-2	HEO	Commercial
257	2 Oct 2000	√		GE-1A	GTO	Commercial
258	13 Oct 2000	√		GE-6	GTO	Commercial
259	22 Oct 2000	√		Glonass (3)	MEO	
260	30 Nov 2000	√		Sirius-3	HEO	Commercial
261	7 Apr 2001	√		Ekran M	GSO	1st Proton M 3rd Breeze M
262	15 May 2001	√		PAS-10	GTO	Commercial
263	16 June 2001	√		Astra 2C	GTO	Commercial
264	24 Aug 2001	√		Cosmos 2379	GSO	
265	6 Oct 2001	√		Globus 1	GSO	
266	1 Dec 2001	√		Uragan (3)	MEO	
267	30 Mar 2002	√		INTELSAT-9	GTO	Commercial
268	7 May 2002	√		DirecTV-5	GTO	Commercial
269	10 Jun 2002	√		Express A1R	GSO	

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
270	25 Jul 2002	√		Araks	LEO	
271	22 Aug 2002	√		Echostar-8	GTO	Commercial
272	17 Oct 2002	√		Integral	HEO	ESA
273	26 Nov 2002	F		Astra-1K	GTO	Commercial - Block DM propulsion unit failure
274	25 Dec 2002	√		Uragan	MEO	
275	30 Dec 2002	√		Nimiq-2	GTO	Commercial - 2^{nd} Proton M 4^{th} Breeze M
276	24 Apr 2003	√		Kosmos	GSO	
277	7 Jun 2003	√		AMC-9	GTO	Commercial
278	24 Nov 2003	√		Yamal-200	GEO	
279	10 Dec 2003	√		Glonass	MEO	
280	29 Dec 2003	√		Express	GSO	
281	16 Mar 2004	√		W3A	GTO	Commercial - 3^{rd} Proton M 7^{th} Breeze M
282	27 Mar 2004	√		Globus	GSO	
283	27 Apr 2004	√		Express AM11	GSO	
284	17 Jun 2004	√		INTELSAT 10-02	GTO	Commercial
285	5 Aug 2004	√		Amazonas-1	GTO	Commercial
286	14 Oct 2004	√		AMC 15	GTO	Commercial
287	30 Oct 2004	√		Express AM1	GSO	
288	26 Dec 2004	√		Glonass	MEO	
289	3 Feb 2005	√		AMC-12	GTO	
290	29 Mar 2005	√		Express AM2	GSO	
291	22 May 2005	√		DirecTV- 8	GTO	
292	24 Jun 2005	√		Express AM3	GSO	
293	9 Sep 2005	√		Anik F1R	GTO	
294	25 Dec 2005	√		Glonass	MEO	
295	29 Dec 2005	√		AMC-23	GTO	
296	28 Feb 2006	F		Arabsat-4A	GTO	
297	17 Jun 2006	√		KazSat	GSO	
298	4 Aug 2006	√		Hotbird 8	GTO	
299	8 Nov 2006	√		Arabsat-4B	GTO	
300	11 Dec 2006	√		Measat 3	GTO	
301	25 Dec 2006	√		Glonass	MEO	
302	9 Apr 2007	√		Anik F3	GTO	
303	7 Jul 2007	√		DirecTV-10	GTO	
304	5 Sep 2007	F		JCSat-11	GTO	
305	26 Oct 2007	√		Glonass	MEO	
306	17 Nov 2007	√		SIRIUS 4	GTO	
307	9 Dec 2007	√		Cosmos 2434	GSO	
308	25 Dec 2007	√		Glonass	MEO	
309	28 Jan 2008	√		Express-AM33	GSO	
310	10 Feb 2008	√		Thor 5	GSO	

Table A.5-1: Proton Operational Launch History (Continued)

	Date (GMT)	Proton Variant		Payload	Orbit Type	Comments
		4-stage	3-stage			
311	14 Mar 2008	F		AMC-14	GTO	
312	27 Jun 2008	√		Cosmos 2440	GSO	
313	18 Aug 2008	√		Inmarsat 4F3	GTO	
314	19 Sep 2008	√		Nimiq 4	GTO	
315	25 Sep 2008	√		Glonass	MEO	
316	5 Nov 2008	√		Astra-1M	GTO	
317	10 Dec 2008	√		Ciel-2	GTO	
318	25 Dec 2008	√		Glonass	MEO	
319	11 Feb 2009	√		Express-AM44/Express MD1	GSO	
320	28 Feb 2009	√		Raduga	GSO	
321	3 April 2009	√		W2A	GTO	
322	16 May 2009	√		ProtoStar II	GTO	
323	30 June 2009	√		Sirius FM-5	GTO	

A.6 FAILURES CAUSES AND CORRECTIVE ACTION

Data was provided by Khrunichev Space Center, which has been placed into the public domain. Failures are noted in Tables A.4-2 and A.5-1.

a) 1970: After 128.3 seconds of flight, 1^{st} stage engine cutoff due to false alarm from the LV safety system activated by the engine pressure gage. Manufacturing defect. Additional check of gages introduced at point of installation.

b) 1972: After 181.9 seconds of flight, 2^{nd} stage automated stabilization system failure due to a relay short circuit in the "pitch" and "yawing" channels caused by elastic deformation of the device housing (which operates in vacuum). Design defect. Design of instruments upgraded and additional testing undertaken.

c) 1975: Failure of 4^{th} stage oxidizer booster pump. Manufacturing/design defect. Cryogen-helium condensate freezing. Booster pump blowing introduced.

d) 1977: After 40.13 seconds of flight, spontaneous deflection of 1^{st} stage engine, loss of stability and engine cutoff at 53.68 seconds into the flight safety system command. Steering failure due to spool-and-sleeve pair manufacturing defect (faulty liner), which caused penetration of hard particles under liner rim and resulted in spool-and-sleeve seizure.

e) 1978: After 87 seconds of flight, loss of stability commenced due to error of 1st stage second combustion chamber steering gear. High temperature impact on cables due to heptyl leak into second block engine compartment. Leak likely developed at heptyl feed coupling to gas generator. Coupling upgraded.

f) 1978: Flight terminated after 259.1 seconds due to loss of LV stability. Automatic stabilization system electric circuit failure in rear compartment of 2nd stage caused by hot gases leaking from second engine gas inlet due to faulty sealing of pressure gage. Gage attaching point upgraded.

g) 1978: After 235.62 seconds of flight, 2^{nd} stage engine shutoff and loss of stability caused by a turbine part igniting in turbo pump gas tract followed by gas inlet destruction and hot air ejection into 2^{nd} rear section. Engine design upgraded.

h) 1982: At 45.15 seconds into the flight, major malfunctioning of 1^{st} stage engine fifth chamber. Flight terminated by LV safety system command. Failure caused by steering motor malfunctioning: first stage of hydraulic booster got out of balance coupled with booster dynamic excitation at resonance frequencies. Hydraulic booster design redefined.

i) 1982: 2^{nd} stage engine failure caused by high-frequency vibrations. Engine design upgraded.

j) 1986: Control system failure due to brief relay contact separation caused by engine vibration. Upgrading included introduction of self-latching action capability for program power distributor shaft.

k) 1987: 4^{th} stage control system failure due to component (relay) defect. Manufacturing defect. Remedial program introduced at supplier's factory. Inspection made more stringent.

l) 1987: 4th stage control system failure due to control system instrument defect. Manufacturing defect. Device manufactured at the time of transfer from developer's pilot production to a factory for full-scale production. Remedial program introduced at relevant factory. No recurring failures recorded.

m) 1988: 3rd stage engine failure caused by destruction of fuel line leading to mixer. Unique manufacturing defect. Inventory rechecked.

n) 1988: 4th stage engine failure due to temperature rise in combustion chamber caused by penetration of foreign particles from the fuel tank. Manufacturing defect. Remedial program introduced at point of manufacture to prevent penetration of foreign particles into tanks. No recurring failures recorded.

o) 1990: 3rd stage engine shutoff due to termination of oxidizer supply. Fuel line clogged by a piece of textile (wiping rag). Remedial program introduced to prevent wiping rags from being left inside engine and LV.

p) 1993: 2nd and 3rd stage engine failures. Multiple engine combustion chamber burn-through caused by propellant contaminants. Remedial program introduced to modify propellant specifications and testing procedures. All launch site propellant storage, transfer, and handling equipment purged and cleaned.

q) 1996: Block DM 4th stage second burn ignition failure. Remedial program involved corrective actions to prevent two possible causes. The first involved introduction of redundant lockers, revised installation procedures, and increased factory inspections to prevent a loosening of a tube joint causing a leak that would prevent engine ignition. The second involved additional contamination control procedures to further preclude particulate contamination of the hypergolic start system.

r) 1996: Block DM 4th stage engine failure during second burn due to malfunction of Mars 96 SC control system, and associated improper engine command sequences. Unique configuration of SC and 4th stage. Remedial program includes stringent adherence to established integration and test procedures.

s) 1997: Block DM 4th stage engine failure resulting from improperly coated turbo pump seal. Remedial program includes removal of unnecessary (for < 4 burn missions) coating.

t) 1999: 2nd stage engine failure due to foreign particles in gas turbine pump. Implemented inspection of internal cavities of second and third stage engines, improved work processes and changed filter design in the ground portion of the fueling system.

u) 1999: 2nd stage engine failure due to foreign particles in gas turbine pump. Installed additional filters in the on-board portion of the fueling system. Developed and implemented new design of the turbo pump unit with increased combustion resistance.

v) 2002: Block DM 4th stage engine failure due to a failed second start sequence of the 11D58M engine (Block DM US), which resulted in a burn-through of the exhaust duct and subsequent shutdown of the flight sequence. The failed second start resulted from fuel being introduced into the gas generator and mixing with O_2 before ignition by the restart fluid. Corrective actions include recertification of quality control procedures at the Block DM manufacturer.

w) 2006: Breeze M 4th stage engine failure. Entry of foreign object debris from oxidizer feed line to the booster turbine inlet. Corrective actions included implementing procedures to validate the cleanliness of oxidizer feed line piping on Breeze M Upper Stage engines.

x) 2007: LV stage 1/stage 2 stage separation failure. Burnthrough of the LV stage 1/stage 2 separation pyrobolt actuation cable. Corrective action is to over-wrap the pyrobolt wiring harness by two layers of asbestos tape with 50% overlap. This increases the heat resistance to well over 400°C, the harness melting point. Additionally the ring and harness are jointly over-wrapped with two layers of tape with 50% overlap impregnated with glue, and the harness was re-routed away from the exhaust gas.

y) 2008: Breeze M 4th stage engine failure. US main engine gas duct burnthrough resulting from the combined maximum environments, gas temperature, gas pressure and thin-walled duct. Corrective action is the implementation of quality provisions that ensures a conduit wall thickness greater than or equal to the 2.5 mm requirement.

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