Mars Missions Failure Report Assortment: Review and Conspectus

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Abstract

Mars has been successfully explored by various space firms. Globally, 44 mission attempts were made and lamentably 27 encountered ineffective. There have been instances where a small misstep in the progressive accomplishment of spaceflight sequence may prompt in extreme loss. In order to refrain this issue, behind every spacecraft loss space agencies mobilizes mishap investigation review board to interpret and release the root basis for the failure of the spacecrafts. However the report, earlier lost space probes lack sufficient and precise data behind their loss. Hence, In this article we review and encapsulate the root causes of entire collapsed spacecraft directed towards Mars since 1960.

Keywords: Failure, Mars, Orbiters, Rovers, Spacecrafts, Trajectory

Introduction

Exploration is one of the attentive endeavor to mankind and a strategy for evolution. We have been incessantly reconnoitering our neighboring planet and universe since twentieth century. The progression of rocketry and planetary science in last decade engendered a futuristic window to explore the red planet which have been a source of inspiration to hundreds of space explorers. It resulted to attempt forty four spacecraft missions globally. But drastically twenty seven missions encountered failure. Ensuing every disastrous attempts, space agencies reveals failure reports with the aid of mishap inquisition board in order to evade spacecraft loss. No reports were assorted unveiling the root causes behind earlier space probes. Hence we scrutinized and recapitulated failure reports of all collapsed spacecrafts.

Mars 1M.No.1

The first ever spacecraft attempted in direction towards Mars that endured in failure. The failure was related to the third stage resonant vibration provoked by faulty gyroscope that ultimately impaired the attitude control system of the launch vehicle. Multitudinous vibrations spawned by synergy other boosters with upper stage booster persecuted the flight. Sequentially, the horizon sensor detached from the booster and the launch vehicle nosedived from the usual flight path angle. As a consequence, the ground commanded third stage engine to halt engine burns posterior to five minutes into the flight, during this phase the spacecraft uplifted to an extent of 120km. Thereafter it re-entered and destroyed in low earth orbit. [1, 2, 3]

Mars 1M.No.2

The Soviet Union launched their second spacecraft predecessor to 1M No.1. But after (T+290) seconds into flight, due to the leakage in oxidizer shut-off valve, it made liquid oxygen to spill around engine’s fuel inlet valve. This leakage ultimately froze the third stage engine fuel (kerosene) resulting failed ignition of 80715K engine caused by shut-off of third stage engine valve, ensuing this issue the spacecraft reached an altitude of 120km above earth surface. As a consequence, the spacecraft failed to achieve LEO and burned up in the earth’s atmosphere.[1, 2, 4, 5, 6]

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Mars 2MV-4 No.1

After two successive failures, Russian encored new spacecraft that successfully lifted-off from the launch pad. Directly after its launch, the block ‘L’ upper stage started to ignite. But the lubricant leaked out of turbo pump and consequently made the main engine to explode and destroy the spacecraft. It was reported that twenty two pieces of spacecraft debris disintegrated and decayed between 29 October 1962 and 26 February 1963. [1, 7]

2 MV-3 No.1

Despite three failures, Soviet Union repeatedly launched 2MV-3 No.1 onboard Molniya launch vehicle. Postliminary to 4 minutes and 33 seconds into flight (T+260 sec). The oxidizer pressurization system malfunctioned ensuing cavitation within the turbo-pump feed lines at T+32 seconds. Despite this issue, the lower stage of the rocket delivered the payload to LEO. But the vibrations caused by either cavitation or stage separation problem displaced the electrical controlling system of ignition engine. Consequently, this obstructed the Block ‘L’ upper stage from igniting and leaving the spacecraft in parking orbit. Following this concerns, the spacecraft started to decay from the next day of its launch. The spacecraft debris remained in orbit until 19 January 1963. [1, 8]

Mars 2MV-4 No.2 (Mars 1)

Excluding four repeated failures, Russians re-attempted Mars 1 whose launch remained success. After the fourth stage separation, the spacecraft left LEO and the solar panels were deployed. Telemetry data indicated that the spacecraft transferred to gyroscopic stabilization state due to the leakage of one of the gas from gas valves in orientation control system. During this notch, sixty-one radio transmission were achieved at five day interval. Following this issue, communication lost due to failure of spacecraft’s orientation system on 21 March 1963. [1, 9]

Mariner 3

The first US spacecraft attempted in the vicinity of Mars. The Mariner 3 inquisition board reported that one hour after the launch, there was no indication of solar panel deployment and all the instruments working properly. Telemetry data suggested that there was a problem in separation due to either launch vehicle or payload fairing. Later, it was identified that a protective heat shield failed to eject after the spacecraft had passed through the atmosphere. Following this, the spacecraft was commanded to jettison its heat shield but nothing happened. Due to which the battery died and the communication terminated from the spacecraft. And the spacecraft failed to achieve trans-Mars trajectory due to its low velocity. The mission remained unsuccessful.[1, 10]

Zond 2

The prime reason behind the failure of the spacecraft was failure in deployment of solar panels during the course of trans-Mars trajectory, caused due to the damage of a tug cord during the Block L upper stage separation from rocket which was designed to pull and deploy the solar panels. Pursuing this concerns, the controllers were able to deploy the solar panels on 15 December 1964, but it was too late to perform midcourse maneuver correction to flyby Mars. Additionally, radiators of the thermal control system and programmed timer also affected during trans-interplanetary injection which led to unsuited thermal condition of the spacecraft. As a result, the spacecraft lost communication and failed in mission accomplishment. [11, 12]
Mars 2M No.521

Soviet Union’s M-69 series - a new generation spacecraft primarily intended for studying Mars from orbit. Consequently after launch especially after the first and second stage booster burns, the third stage ignition did not instate on time. Several investigations reveals that due to imbalance of rotor in the third stage booster’s oxidizer pump resulting in the loss of thrust and vehicle separation. Following this issue, the booster exploded and impacted in the mountains of Altai. [13, 14]

Mars 2M No.522

Similar to its predecessor, Russians re-attempted M-69 spacecraft (2M No.522). Disparate studies conceded that, immediately after launch first stage engine of proton K/D UR-500 caught fire while lift-off. The fire was most likely to be caused by leakage of nitrogen tetroxide fostered by lack of drain plug. Beside this issue, remaining engines insisted stage burns to remunerate the flight for 30 seconds. But the thrust section went out of control and the rocket began to tilt horizontally before the engines were manually commanded to shut-off stage burns from their appropriate ground controllers. Eventually the rocket nosedived into the ground covering the launch complex after 41 seconds into the flight. [14, 15, 16]

Mariner 8

Earlier investigation reported that, the main cause for the failure of Mariner 8 was failure of entire guidance system during the course of activating the autopilot function. Subsequent analysis unveiled that, a diode equipped for protecting the spacecraft system from transient voltages was damaged during the replacement/ installation of pitch amplifier circuit board which led to the launch vehicle malfunction and failed launch.[17, 18]

Kosmos 419

The first of the fifth generation spacecraft of Soviet Union launched to overtake US Mars probes. After its launch, the vehicle successfully injected the spacecraft into low earth parking orbit, But the Block D upper stage of Molniya rocket failed to ignite as the ignition timer was incorrectly set. Later investigation showed that there was human error in programming eight digit code to ignition timer. The timer had been set to ignite after 1.5 years instead of 1.5 hours to perform trans-mars trajectory maneuver. The result of which, the spacecraft re-entered and decayed in the upper atmosphere on 12 May 1971 just posterior to two days of its launch. [11, 19]

Mars 2 Lander

Russia’s first Mars probe to carry both orbiter and lander. The probe successfully approached Mars. But, at 4.5 hours before reaching Mars, the Mars 2 descent module separated from the orbiter on 27 November 1971. The descent module entered the Mars atmosphere relatively at 6 km/s. Following this phase, the lander malfunctioned and entered at a steep angle. EDL sequence did not occur as programmed and the parachute did not deploy. As a result the lander made a great impact and crashed on the surface approximately at 45° 47'. [18, 20, 21]

Mars 3 Lander

The first artificial object to perform effective landing on any other planetary surface. After successful touchdown, the communication between earth stations and the lander module was established via Mars 3 orbiter. Approximately at 13:52:25 UTC (nearly 20 seconds after landing) the transmission ceased for unknown reasons and no further communication was re-established. It is still uncertain that whether the problem persisted in the lander or the communication relay on the orbiter. The lander malfunction is related to extreme Martian dust storms may have damaged the communication system thereby inducing coronal discharge. [22, 23]
**Prop-M Rover**

Both Mars 2 and Mars 3 lander had 4.5 kg Prop-M rover along with two penetrometer intended to measure the density of Martian soil. However, one rover lost with Mars 2 lander crash and another rover with Mars 3 lander was never deployed on the surface. [24]

**Mars 4 Orbiter**

Mars 4 was one of the 3M (M-73) spacecraft plighted to study Mars from trajectory path. Succeeding its launch the Proton’s Block-D upper stage engine successfully placed the spacecraft into Trans-Mars trajectory path. After trajectory correction performed on 30 July 1973, two of three channels of onboard computers failed due to defective transistor which led to the malfunction of breaking engine plighted for second mid-course correction. As a result, the probe failed to achieve Mars orbit on 10 February 1974. Rather than its failures, ground controllers were able to command the spacecraft to transmit data, it transmitted radio occultation data and two panoramic surface images of Mars in the midst of flyby. [11, 21, 25, 26]

**Mars 6 Lander**

The Mars 6 became the second human-made object to effectuate successful landing on Mars. During the course of Mars transit eminently after the first mid-course correction on 13 August 1973, there was a trouble in telemetry system indicating difficulty in establishing communication. The problem was most likely to be caused by the effect of bad 2T312 transistor which were responsible for failure onboard computer of past Mars 4 orbiter. Despite of telemetry issue, the spacecraft operated autonomously and pursued its function as programmed. The lander separated from flyby bus orbiter on 12 March 1974 and entered Martian atmosphere. Subsequently, the parachute system deployed to cut down the terminal velocity. Preliminary to its precision landing, the ground controllers lost communication from the lander. Later investigations estimated that, due to its landing in geographically rough terrain it may have damaged the radio communication system. However the failure, the landers transmitted atmospheric data via Mars 6 telecommunication relay while descending. [11, 21, 22, 25, 26]

**Mars 7 Lander**

Mars 7 the fourth spacecraft of M-73 series successfully launched and inserted into Mars trajectory path. En route to Mars, it encountered communication issue and ground controllers were coerced to communicate via radio communication system. On 9 March 1974, landing module denied separation command from flyby bus, but latterly separated. Consequently the main retro rocket engine failed to ignite in order to initiate hypersonic atmospheric entry, but the failed ignition was identified due to installation of faulty transistor in onboard computer circuits. Finally, the entry vehicle missed the planet by 1,300 km and entered heliocentric orbit. [11, 21, 22, 26]

**Phobos 1**

Soviet Union’s 1988-Phobos 1 & Phobos 2 were acquisitive missions propelled towards Martian moon (Phobos). On 1 September 1988 in transit to Phobos, Phobos 1 did not respond to multiple command request indicating intricate in establishing communication with the ground controllers during planned session. Investigation reported that, at the interim of communication session on 28 August 1988, a wrong command programmed by a ground controller was transmitted to Phobos circumventing the proofread of computer which eventually turned-off the thrusters of attitude control system/stabilization system and orientation system. Ensuing this issue, Phobos 1 transposed its solar panel orientation away from the sun which readily discharged the battery leading to the loss of power requisite to respond to the powerful radio signals from earth. Consequently, the communication from Phobos 1 was ceased terminating the mission strategies. [11, 27, 28, 29, 30]
Phobos 2

Phobos 2 was partially success mission, on 27 March 1988 after changing its orientation to image Phobos, it encountered radio communication loss. Several attempts were made to re-establish radio contact that remained unsuccessful. Four hours later, ground controllers received a weak signal indicating the spacecraft spinning in off-design mode and lost all its orientation that adversely affected the spacecraft system from generating power. The main cause for the failure of Phobos 2 was again due to failure of orientation system which caused by simultaneous malfunction in both channels of onboard spacecraft computer. [11, 27, 31]

Mars 96

Mars 96 was the heaviest spacecraft mission ever attempted in 20th century as well as the only planetary probe of Soviet Russia in twelve years since Phobos mission. Rear to its launch on 16 November 1996, the carrier rocket Proton successfully placed the spacecraft into parking orbit. But the Block D-2 fourth stage malfunctioned and failed to ignite. Consequently the spacecraft re-entered the earth’s atmosphere and crashed somewhere near Chile. Later on investigation team failed to portray exact reason behind Mars 96 fourth stage ignition failure due to lack of telemetry data during missions. [32, 33, 34]

Mars Observer

Seventeen years after the Viking Program, US launched Mars Observer for detailed scientific observation of Mars. The probe successfully completed interplanetary cruise to Mars. On 21 August 1993, three days prior to Mars orbital insertion, Mars Observer lost communication from ground controllers significantly due to problem emerged as a result of inappropriate pressurization of rocket thruster fuel tanks [35, 36, 37]. Several attempts were made to re-establish the communication but the attempts remained unsuccessful. Latterly, extensive analysis revealed that the major reason for the loss of spacecraft was due to rupture of fuel tank provoked by improper fuel pressurization of propulsion system on board spacecraft resulting in the exhalation of liquid mono methyl hydrazine and helium gas beneath spacecraft’s thermal blanket.

The leakage was endorsed as a result of inadvertent mixing of nitrogen tetroxide (NTO) and mono methyl hydrazine (MMH) in pressurized titanium tube during helium pressurization and their reactions have ruptured the tubing system. The unsymmetrical leakage of fuel, made the spacecraft to spin at a higher rate which adversely affected the transmitter switching and solar arrays orientation resulting in expeditious discharge of batteries and loss of power. Beside this issue, the leaked mono methyl hydrazine impaired the electrical circuits onboard spacecraft. In addition to this, multiple factor such as impairment of electrical power system caused by short circuit of regulated power bus, failure of fuel tank pressurization regulator, rapid expulsion of NASA Standard initiator from a pyro valve that damaged the fuel tank, failure of computation function of spacecraft and failure of transmitters were also related to the loss of spacecraft.[36, 38, 39, 40]

Nozomi

Japan’s first step to explore Mars began with the launch of Nozomi (Planet-B) on 03 July 1998. After successful launch, Nozomi performed powerful gravitational pull on 20 December 1998 due to defective thrust valve following two lunar gravity assist on 24 August and 8 December 1998 thereby travelling 1000km. During this critical stage, the spacecraft consumed excess fuel than anticipated. Following this issue, Nozomi effectuated two earth gravity assist to propel itself in trajectory towards Mars. Ultimately the electrical system and the S-band communication system were imparted by solar eruption in April 2002 that provoked communication issues with the spacecraft. Moreover the failure of electrical system affected the thermal control system which solidified spacecraft propellant required for maneuvering.

Subsequent attempts were made to heat the frozen propellant with solar radiation that remained ineffective. On 9 December 2003, the Nozomi team failed to rectify the trajectory maneuver after repeated attempts and concluded to terminate the mission. Afterwards the controllers cruised off the spacecraft to heliocentric orbit in order to avoid impact with other Marscraft. [41, 42, 43, 44, 45]
Mars Climate Orbiter

United States last orbiter mission of twentieth century, Mars Climate Orbiter was successfully launched and intended to study the Martian climate. However the probe failed prior to Mars orbital insertion. The Mars Climate Orbiter’s Mishap Investigation Board obigated that the core reason for the loss of spacecraft was the failure in utilizing metric units [46, 47, 48, 49, 50, 51]. The thruster performance data was to be in SI (metric) units rather than English units in a software file entitled “Small Forces”. As a result the Mars Surveyor Operation Project’s System Interface Specification software was instructed to use thrust units as pounds-seconds (lbf-s) instead of Newton-seconds (N-s) which led to the computation of spurious trajectory path. Consequently the spacecraft entered the Martian atmosphere at a lower altitude resulting in the destruction of spacecraft in the upper atmosphere or re-entered into heliocentric orbit.

Additionally, untraveled changes in spacecraft velocity, anomalous nature of navigation team with the spacecraft, interruption of 5th trajectory maneuver correction, inadequate system engineering process, improper link between project elements, lack of navigation team staffing and training including faulty verification and validation process were also considerable factors for loss of Mars Climate Orbiter spacecraft. [52, 53, 54, 55, 56, 57]

Mars Polar Lander

Mars Polar Lander or Mars Surveyor 98 lander was successfully launched and approached Mars. On 03 December 1999 after the cruise stage separation from the flyby bus, the lander module performed hypersonic atmospheric entry. At entry altitude the antenna adverted off-Earth leading to the loss of communication from ground controllers. The prime cause for the loss of communication is ascertained. However no signals were received from Mars Polar Lander as well as Deep Space 2 probe. [58, 59, 60, 61, 62]

The presumable factor for the loss of MPL is unanticipated shutdown of lander’s retrorocket engine due to weird signals spawned by flawed MPL flight software in the interim of descent phase. The unauthentic signal would have indicated that the lander had landed before landing due to incorrect identification of vibrations provoked during leg deployment phase. Consequently the software persuaded the engine to shut down. The status of the lander is still uncertain due to lack of flight data. It is difficult to predict whether the lander had touched down or crashed into the surface. [63, 64, 65]

Beagle 2 Lander

European Space Agency’s made excellent landing on Mars in their first attempt. After performing effective landing on 25 December 2003, Beagle 2 have contacted 2001 Mars Odyssey but the ground controllers failed to receive signal. Several attempts were made to establish communication that remained unsuccessful. Eventually no communication was ever re-established and declared lost on 6 February 2004. [66, 67, 68, 69]

The fundamental cause for the loss of Beagle 2 is still uncertain due lack of successful flight data from lander module during EDL performance. And it is very difficult to prognosticate the cause for failure. Hence, the Beagle 2 investigation board released two reports after six months of internal investigation that summarizes two possibilities for the failure of lander (i.e., technical and programmatic issue). In addition to this, several considerable factors such as robustness nature of air-bad design, inadequate testing Programme, the possibility of collision between back cover and the main parachute of lander module, premature deployment of lander from the air-bag landing system are also censurable for the loss of Beagle 2 lander. [70, 71, 72]
Fobos-Grunt

Fobos Grunt was Soviet Union’s sample return mission cruised to moon Phobos. The probe Fobos-Grunt along with Yinghuo-1 (Chinese Mars Orbiter) uplifted onboard Zenit-2SB41 launch vehicle on 08 November 2011. Sequentially Zenit injected the spacecraft into LEO, after successful orbiter insertion the scheduled cruise stage firing did not take place to propel the spacecraft towards Mars trajectory. The failed ignition was due to malfunction of onboard computers caused by concurrent reboot of its two channels. The impairment of computers was either due to radiation damage of electronic chips or installation of ill-equipped electronic components. The collapse of onboard computer program due to ruined chip made the spacecraft computer to reboot persistently leaving the spacecraft stranded in low earth orbit. Eventually the stage burn never occurred and the spacecraft destroyed during re-entry.[73, 74, 75, 76, 77, 78, 79, 80]

Yinghuo-1

Yinghuo-1 was the first Chinese interplanetary spacecraft intended to detect and observe Martian magnetosphere and ionosphere studies [81]. This spacecraft lost along with Russian’s Fobos-Grunt mission on 15 January 2012 and its disintegrated parts fell over Pacific Ocean. [82, 83]

Schiaparelli EDM Lander

European Space Agency’s second attempt to land on Mars with Schiaparelli demonstration module remained unsuccessful. The lander review board revealed that during the course of landing attempt, ground controllers unexpectedly lost communication from the lander just one minute ahead of scheduled touchdown. Following communication failure, the lander performed automated landing. During the course of entry, descent and landing phase, the unexpected fluctuation in dynamics of the landing vehicle made the gyroscope (Inertial Measure Unit) incapable of calibrating higher readings. The failure of gyroscope provoked fatal error in guidance and control system. Thus the EDL flight software generated negative altitude data (below ground level) resulting in premature lander separation and hard impact onto the surface. Furthermore considerable factors such as inadequate enduring time of IMU, inadequate handling of IMU, inadequate design robustness and contingency in hardware management are also accountable for mishap of lander. [84, 85, 86, 87, 88, 89]

Conclusion

This paper represents failure reports of entire spacecrafts targeted towards Mars. Most of the preceding spacecrafts lost due to obstacle in launch vehicle performance and booster stage ignition that have been enhanced nowadays. But modern spacecrafts attempted after Mars 96 encountered technical issue that has to be taken into consideration for future prospects. Insight to future prosperous Mars missions, several investigation articles has been thoroughly analyzed and the root causes for all the unsuccessful Mars crafts has been precisely summarized. Additionally major issue and their consequences has also been comprehensively tabularized in table 1 and the mission target achieved during spaceflight in their transit sequence from Earth to Mars has been perceivably shown in table 2.
Table 1: Spaceflight sequence - Target achieved during mission

| S.No | Spacecraft | LNH | SB | BSS | LEOI | VSS | COM-1 | OMB | TMTI | COM-2 | TCM | MA | COM-3 | CSS | OIB | OI | HBE | HSJ | PDD | RPD | AD | COM-4 | LDNG | COM-5 |
|------|------------|-----|----|-----|------|-----|-------|-----|------|-------|-----|----|-------|-----|-----|----|-----|-----|-----|-----|-----|-----|------|-------|-----|
| 1    | 1M No.1    |     |    |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 2    | 1M No.2    |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 3    | 2MV-4 No.1 |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 4    | Mars 1     |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 5    | 2MV-3 No.1 |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 6    | Mariner 3  |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 7    | Zond 2     |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 8    | 2M No.321  |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 9    | 2M No.322  |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 10   | Mariner 8  |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 11   | Kosmos 419 |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 12   | Mars 2 Lander |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 13   | Prop-M Rover |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 14   | Mars 3 Lander |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 15   | Prop-M Rover |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 16   | Mars 4 Rover |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 17   | Mars 4 Lander |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 18   | Mars 5 Lander |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 19   | Phobos 1   |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 20   | Phobos 2   |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 21   | Mars Observer |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 22   | Mars 96 Orbiter |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 23   | Mars 96 Lander |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 24   | Mars 96 Penetrator |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 25   | Nozomi     |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 26   | MCO        |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 27   | MPL        |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 28   | Deep Space 2 |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 29   | Beagle 2   |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 30   | Phobos-Grunt Orbiter |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 31   | Phobos-Grunt Lander |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 32   | Yinghuo-1 |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |
| 33   | Schiaparelli EDM Lander |     |     |     |      |     |       |     |      |       |     |    |       |     |     |    |     |     |     |     |     |     |     |     |     |

**NOTE:** LNH - Launch, SB - Stage Burns, BSS - Booster Stage Separation, LEOI - Low-Earth Orbit Insertion, VSS - Vehicle Stage Separation, COM-1 - Communication-1, OMB - Orbital Maneuver Burn, TMTI - Trans-Mars Trajectory Insertion, COM-2 - Communication-2, TCM - Trajectory Correction Maneuver, MA - Mars Approach (Arrival), COM-3 - Communication-3, CSS - Cruise Stage Separation, OIB - Orbital Insertion Burn, OI - Orbital Insertion, HBE - Hypersonic Ballistic Entry, HSJ - Heat Shield Jettison, PDD - Parachute Deployment Descent, RPD - Retrorocket Powered Descent, AD - Aerodynamic Deceleration, COM-4 - Communication-4, LDNG - Landing (Ground Touchdown), COM-5 - Communication-5.

- Target Achieved × Failed □ Pursuing Issue
| S.No | Spacecraft | Type   | Launch   | Launcher | Launcher Type | Country | Issue                                                                 | Outcomes                                        |
|------|------------|--------|----------|----------|--------------|---------|----------------------------------------------------------------------|-------------------------------------------------|
| 1    | 1M No.1    | Flyby  | 10 Oct 60 | Molniya  | 8K78/L1-4   | USSR    | Launch failure                                                        | Disintegrated in LEO                             |
| 2    | 1M No.2    | Flyby  | 14 Oct 60 | Molniya  | 8K78/L1-5   | USSR    | Failed Ignition                                                       | Never achieved LEO                               |
| 3    | 2MV-4 No.1 | Flyby  | 24 Oct 62 | Molniya  | 8K78/T-103-15 | USSR    | Rocket exploded                                                       | Spacecraft destroyed                             |
| 4    | Mars 1     | Flyby  | 01 Nov 62 | Molniya  | 8K78/T103-16 | USSR    | Orientation Failure                                                  | Lost communication before flyby                 |
| 5    | 2MV-3 No.1 | Lander | 04 Nov 62 | Molniya  | 8K78/T103-17 | USSR    | Failed Ignition                                                       | Disintegrated in LEO                             |
| 6    | Mariner 3  | Flyby  | 05 Nov 64 | Atlas    | LV-3 Agena-D | USA     | Stage Separation                                                      | Lost communication                               |
| 7    | Zond 2     | Flyby  | 30 Nov 64 | Molniya  | 8K78       | USSR    | Delayed Solar Panel Deployment                                        | Lost communication                               |
| 8    | 2M No.521  | Orbiter| 27 Mar 69 | Proton   | K/D UR-500  | USSR    | Failed Ignition                                                       | Booster exploded destroying the craft            |
| 9    | 2M No.522  | Orbiter| 2 Apr 69  | Proton   | K/D UR-500  | USSR    | Booster fire accident                                                 | Rocket nosedived into the ground                |
| 10   | Mariner 8  | Orbiter| 09 May 71 | Atlas    | SLV-3C Centaur D | USA    | Failure of Transistor and Guidance Control System                      | Launch failure                                  |
| 11   | Kosmos 419 | Orbiter| 10 May 71 | Proton   | K/D UR-500  | USSR    | Improper stage ignition                                               | Re-entered atmosphere and decayed               |
| 12   | Mars 2     | Lander | 19 May 71 | Proton   | K/D UR-500  | USSR    | Lander malfunctioned                                                  | Crashed on the Martian surface                  |
| 13   | Prop-M     | Rover  | 19 May 71 | Proton   | K/D UR-500  | USSR    | -                                                                     | Lost with Mars 2 lander                         |
| 14   | Mars 3     | Lander | 28 May 71 | Proton   | K/D UR-500  | USSR    | Lander’s communication system impaired on Mars                        | Lost communication from ground                  |
| 15   | Prop-M     | Rover  | 28 May 71 | Proton   | K/D UR-500  | USSR    | -                                                                     | Never deployed from Mars 3 lander              |
| 16   | Mars 4     | Orbiter| 21 Jul 73 | Proton   | K/D UR-500  | USSR    | Onboard computer failure due to defective transistor                  | Failed to perform Orbital Insertion             |
| 17   | Mars 6     | Orbiter| 05 Aug 73 | Proton   | K/D UR-500  | USSR    | Lander’s radio communication system impaired                          | Lost contact due to Martian rough terrain       |
| 18   | Mars 7     | Lander | 09 Aug 73 | Proton   | K/D UR-500  | USSR    | Onboard computer failure / failed retrorocket ignition                | Failed to enter Martian atmosphere              |
| 19   | Phobos 1   | Orbiter| 07 Jul 88 | Proton   | K/D UR-500  | USSR    | Wrong Programme commanded                                             | Lost communication from ground                  |
| 20   | Phobos 2   | Orbiter| 12 Jul 88 | Proton   | K/D UR-500  | USSR    | Failure of Orientation System                                          | Lost radio communication                       |
| 21   | Mars Observer | Orbiter| 25 Sep 92 | Titan    | III        | USA     | Spacecraft malfunctioned / short circuit                              | Lost communication                              |
| 22   | Mars 96    | Orbiter| 16 Nov 96 | Proton   | K/D-2 UR-500 | USSR    | Failed Stage Ignition                                                 | Decayed and crashed on earth                    |
| 23   | Mars 96    | Lander | 16 Nov 96 | Proton   | K/D-2 UR-500 | USSR    | Failed Stage Ignition                                                 | Decayed and crashed on earth                    |
| 24   | Mars 96    | Penetrator | 16 Nov 96 | Proton   | K/D-2 UR-500 | USSR    | Failed Stage Ignition                                                 | Decayed and crashed on earth                    |
| 25   | Nozomi     | Orbiter| 03 Jul 98 | MV       | -          | JAPAN   | Electrical and Communication system impaired                         | Solar radiation impaired the craft and lost     |
| 26   | MCO        | Orbiter| 11 Dec 98 | Delta    | II 7425    | USA     | Unit conversion software issue (IMU)                                 | Destroyed in upper Mars atmosphere              |
| 27   | MPL        | Lander | 03 Jan 99 | Delta    | II 7425    | USA     | Flight software / Premature engine shutdown                          | Lost signal and landing is uncertain            |
| 28   | Deep Space 2 | Penetrator | 03 Jan 99 | Delta    | II 7425    | USA     | -                                                                     | No signal was received                          |
| 29   | Beagle 2   | Lander | 02 Jun 03 | Soyuz    | FG/Fregat  | USA     | Technical and programmatic issue                                     | Lost communication from ground                  |
| 30   | Fobos-Grunt | Orbiter | 08 Nov 11 | Zenit    | 2M/2FG    | USSR    | Onboard Computer malfunction and failed ignition                     | Destroyed during re-entry                       |
| 31   | Fobos-Grunt | Lander | 08 Nov 11 | Zenit    | 2M/2FG    | USSR    | Onboard Computer malfunction and failed ignition                     | Destroyed during re-entry                       |
| 32   | Yinghao-1  | Orbiter| 08 Nov 11 | Zenit    | 2M/2FG    | CHINA   | -                                                                     | Lost with Fobos-Grunt mission                   |
| 33   | Schiaparelli | Lander | 14 Mar 16 | Proton   | M/Briz-M  | EUROPE | Failure of Inertial Measurement Unit                                 | Crashed on the planetary surface                |
Conflict of Interest

The authors have no conflicts of interest to report.

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Nomenclature
LEO - Low Earth Orbit
MV - Mars Venus
T - Time (T+)
EDL - Entry, Descent and Landing
UTC - Universal Time Coordinated
NTO - Nitrogen Tetroxide
MMH - Mono Methyl Hydrazine
NASA - National Aeronautics Space Administration
ESA - European Space Agency
MCO - Mars Climate Orbiter
MPL - Mars Polar Lander
DS 2 - Deep Space 2
EDM - Entry, Descent, Module
IMU - Inertial Measurement Unit
USSR - Union of Soviet Socialists Republic (Soviet Russia)
US - United States
USA - United States of America
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