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Research Article: Orbital Launch Anomalies as a Mechanisms of Motion of Space Rockets through MIRCE Space

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Orbital Launch Anomalies as a Mechanisms of Motion of Space Rockets through MIRCE Space

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Abstract:
The main objective of this paper is to briefly describe several orbital launches where space rockets of different types have either never made it to space or failed to deploy their payloads once they got there. The common denominator for a failure of each space rocket type, according to publicly available information provided by their management and sponsoring teams, was a launch anomaly. Based on the extremely short duration of all missions considered, the most probable mechanisms that caused orbital launch anomalies, in accordance to the MIRCE Science theory, have been induced into rockets by human actions during: design, production, assembly, transportation or launch processes. As the anomalies occurred on space rockets that are designed, produced and launched by different companies, located on different continents, it could be concluded that human errors are a generic phenomenon of the human race. The orbital launch anomalies observed in this paper are in agreement with the 5th Axiom of MIRCE Science that states, "Probability of human error in execution of any task is greater than zero". [1]

Key words: MIRCE Science, space rackets, orbital launch anomalies, inherent failure mechanisms, human errors

1. Introduction: The philosophy of MIRCE Science is based on the premise that the purpose of the existence of any in-service system is to do work. The work is considered to be done when the expected measurable function is performed through time. MIRCE Science focuses on the scientific understanding and description of the physical phenomena and human rules that govern the motion of in-service systems through MIRCE Space. A full understanding of the mechanisms that generate this motion is essential for the accurate predictions of the expected work done of a given in-service system type using the mathematical scheme of MIRCE Science. [1]

A rocket, like any other functional system, is a design chosen collection of components with complicated interactions that are assembled in a predetermined way to do work, which is done when a measurable function is performed, like: speed, altitude, range, deployable load and so forth. As a rocket functions in accordance to known mechanisms its performance is accurately predictable.

However, the mission of each rocket type is driven by an uncertain collection of interactions between natural and human actions that determine its unique in-service performance, like a payload delivered, trajectory reached and similar. Hence, as each real-time mission of each individual rocket is a unique sequence of actions and events some launches generate undesirable consequences on its in-service performance. [1]

The main objective of this paper is to briefly describe several missions where rockets of different designs have either never made it to space or failed to deploy their payloads once they got there. However, according to publicly available information provided by their management and sponsoring teams, the common denominator for a failure of each individual rocket was a launch anomaly. [2]

2. MIRCE Science Fundamentals

According to MIRCE Science, at any instant of calendar time, a given in-service system could be in one of the following two macro states Knezevic [2]:

• Positive Functionability State (PFS), a generic name for a state in which a in-service system is able to deliver the expected measurable function(s),

• Negative Functionability State (NFS), a generic name for a state in which an in-service system is unable to deliver the expected measurable function(s), resulting from any reason whatsoever.

In MIRCE Science, work done by an in-service system is uniquely defined by the trajectory generated by its motion through MIRCE Space . That motion is driven by functionability actions, which are classified as:

• Negative Functionability Action (NFA), is a generic name for any natural process or human activity that compels a system to move to a NFS. Typical examples are: thermal ageing, actinic degradation, acid reaction, bird strike, warping, abrasive wear, suncups formation on the blue ice runway, fatigue, pitting, thermal buckling, photo-oxidation, production errors, strong wind, maintenance error, hail damage, lightening strike, COVID-19, quality problems in production or installation, tsunami, sand storm and so forth.

• Positive Functionability Action (PFA), is a generic name for any natural process or human activity that compels a system to move to a PFS. Typical examples are: servicing, lubrication, visual inspection, repair, replacement, final repair, examination, partial restoration, inspection, storage, modification, transportation, sparing, cannibalisation, refurbishment, health monitoring, restoration, packaging, diagnostics and similar

To scientifically understand the mechanisms that generate functionability actions, positive and negative, analysis of the in-service behaviour of several thousands of components, modules and assemblies of in-service systems in defence, aerospace, nuclear, transportation, motorsport, communication and other industries have been conducted at the MIRCE Akademy.

In MIRCE Science all negative functionability actions regarding individual components are categorised as following [2]:

• Component-internal actions (CIA) that consist of:

o Inherent discrete actions, ICIA,

o Cumulative continuous actions, CCIA,

• Component-external actions (CEA), which are originated by:

o Environmental phenomena, ECEA

o Human activities, HCEA,

Corresponding negative functionability actions regarding the whole system are categorised as following [2]:

• System-internal actions (SIA)

• System-external actions (SEA):

o Discrete environmental phenomena

o Human activities

The remaining part of the paper is analysing the mechanisms of the actions that generated undesirable in-service events during the recent orbital launches of space rockets that are named “anomalies” by their operators.

3. Launch Anomaly of First ABL Space RS1 Rocket

ABL, a Californian based company founded in 2017, had postponed several launch attempts since November 2022 due to technical issues and bad weather, including aborts during the engine start-up sequence just before lift-off. The launch campaign followed a static test firing of the RS1 rocket’s first stage and a series of fuel loading demonstrations at Kodiak. The two-stage RS1 rocket is capable of placing a payload of nearly 1,350 kg into a low-altitude equatorial orbit, or around 970 kg into a high 500-km polar orbit. The company adopted a “containerised launch solution,” that allows a deployment of ground support equipment and rockets to different spaceports with minimal pre-existing ground infrastructure.

The ABL’s first lift-off of the 27m tall RS1 rocket took place at the Pacific Spaceport Complex on Kodiak Island, Alaska, on 10th January 2023. The rocket was supposed to head south over the Pacific Ocean on an attempt to place two small satellites into polar orbit about 300 km above Earth. However, all nine of RS1’s E2 engines shut down simultaneously destroying itself and the cargo. Inevitably the launch facility was damaged, but all personnel were safe. ABL is investigating the launch failure, in coordination with the Federal Aviation Administration and Alaska Aerospace Corporation, which owns the spaceport on Kodiak Island . [3]

Early failure investigation hinted that a “Shortly before power loss, a handful of sensors began dropping out sequentially. This evidence suggests that an unwanted fire spread to avionics system, causing a system-wide failure”. The RS1’s first stage suffered a complete loss of power 10.87 seconds after lift-off. The rocket continued to ascend for another 2.63 seconds, reaching a maximum altitude of 232 meters but then fell back to Earth, impacting about 18 m east of its launch pad. As 95% of the total propellant mass was still onboard, an energetic explosion to and over-pressure wave where generated that caused damage to nearby equipment and facilities, including communications system at the pad, as well as fuel and water storage tanks. The crash scattered debris over an area with a radius of 0.40 km and sparked a fire that destroyed an ABL fabric hangar and much of the equipment contained.

4. Launch Anomaly of Virgin Orbit’s First UK Satellite Launch

Virgin Orbit rocket LauncherOne using the Boeing 747-400, named Cosmic Girl, a launch vehicle that had flown on all the previous missions. The B747, registration N744VG, had the entire main deck interior, including all seats and overhead bins removed to reduce the weight. The upper deck was transformed into a small mission control room for Launch Engineers to oversee missions during flight. It arrived to Cornwall on 11th October 2022, closely followed by the ground support equipment (GSE) and the LauncherOne rocket, which arrived on the board of a C-17 military aircraft. The payload consisted of nine satellites from the UK's Ministry of Defence, the sultanate of Oman, the US National Reconnaissance Office and British start-up Space Forge. Spaceport Cornwall, is a newly inaugurated rocket lancing facility in the UK.

On the 9th January 2023 the mission lifted off shortly after 22:00 GMT, when the Cosmic Girl carried the LauncherOne rocket system to the designated drop zone. It maintained a looping "racetrack" pattern as it awaited the final clear to launch call from mission command. At 35,000ft above the Atlantic, off Ireland's southern coast, just before 23:15, the rocket was successfully released and then ignited its engines, quickly going hypersonic and successfully reaching space while Cosmic Girl started the return flight to Spaceport Cornwall.

The rocket, that was scheduled to pass Antarctica and Australia before enacting a final burn to take it into Low Earth Orbit and releasing its payload, continued through the successful stage separation and ignition of the second stage. At some point during the firing of the rocket's second-stage engine, the system experienced what officials have described only as an "anomaly," and the rocket, which was travelling at a speed of more than 17600 km/h, failed to reach the target orbit. The early thrust termination ended the mission, and the second stage of LauncherOne failed a few minutes after the carrier jet released it. The rocket and its nine small satellite payloads re-entered the atmosphere burned up near the Canary Islands.

On the 15 February 2023 Virgin Orbit Tweeted the following statement , "The data is indicating that, from the beginning of the second stage first burn, a fuel filter within the fuel feedline had been dislodged from its normal position. Additional data shows that the fuel pump that is downstream of the filter operated at a degraded efficiency level, resulting in the Newton 4 engine being starved of fuel. Performing in this anomalous manner resulted in the engine operating at a significantly higher than rated engine temperature."

5. Launch Anomaly of Arianespace Vega C rocket

The Vega rocket family is designed in partnership between the Italian company Avio S.p.A. and the European Space Agency to carry small to medium-size satellites into orbit.

From the entry into service in 2012 Vega rocket launcher had 14 straight successful flights. However, there were 3 launch failures among remaining 8 flights, during the last 4 years. Silent details of them are highlighted in the text below.

5.1 First Launch Anomaly of Vega Rocket in 2019

Arianespace published findings from an Independent Inquiry Commission tasked to analyse the failure of Vega Flight VV15 in July 2019 and to make recommendations to resume launches with a required level of safety, security and reliability. [4]

According to the Commission Vega's launch appeared nominal, with the first stage booster firing the rocket and the payload, the United Arab Emirates' FalconEye-1 satellite system, from the ELA-1 pad at the European Spaceport in French Guiana. The operation of the P80 first stage (engine ignition, atmospheric phase, P80 propulsion and separation) was nominal; all parameters were as expected and in line with those from preceding flights. It burned for one minute and 54 seconds, accelerating the rocket to a velocity of 1.78 km/s to the altitude of 53 km. It separated at burnout, with the second stage supposed to ignite its Zefiro 23 motor almost immediately for what was expected to be a one-minute, 43-second burn. The ignition and powered phase of the Z23 stage was as expected during the first 14s 25ms and all functionality related parameters were as expected and in line with those for preceding flights.

However, the investigation noted that at 130s and 850ms, "a sudden and violent event occurred on the Z23 motor. This event led to a break-up of the launcher in two main parts: the Z23; and the assembly composed of the fairing, satellite, flight adapter, AVUM and the Zefiro 9 stage (Z9)".

The investigation identified the most likely cause of the launch anomaly was a "thermo-structural failure in the forward dome area of the Z23 motor". It added that other possible causes, such as inadvertent activation of the neutralisation system, have been found unlikely . The Commission has proposed: an exhaustive verification plan of its findings based on analyses and tests that should set of corrective actions on all subsystems, processes and equipment concerned.

5.2 Second Launch Anomaly of Vega Rocket in 2020

On 17 November 2020 the Vega rocket's upper stage control system caused the launcher to tumble minutes after lift-off. The failure resulted in the loss of a Spanish Earth observation satellite and French research probe.

Engineers from Arianespace reviewed telemetry data and found the most likely cause of the launch anomaly was a case of human error. They concluded that cables leading to thrust vector control actuators on the upper stage were inverted, apparently a mistake from the assembly of the upper stage engine. The thrust vector control system pivots the upper stage engine nozzle to direct thrust, allowing the rocket to control its orientation and steering [5]. The cabling problem caused the engine to move its nozzle in the wrong direction in response to commands from the rocket's guidance system. That resulted in the rocket losing control and tumbling just after ignition of the upper stage engine around eight minutes after launch. According to Arianespace the inverted cables were a "human error," and not a design problem.

5.3 Third Launch Anomaly of Arianespace Vega C Rocket in 2022

On 20th December 2022 an Arianespace Vega C rocket, aimed to launch the Pléiades Neo 5 and 6 satellites for Airbus' Pléiades Neo constellation into a polar orbit about 620 km above Earth, from Europe's Spaceport in Kourou, French Guiana. [6]

The Vega C is the 35 m toll, four-stage rocket, which is a more powerful version of the Vega, which first flew in 2012. The Vega C can carry around 2,300 kg of payload to a high of 700 km sun-synchronous orbit, compared to 1,500 kg for the older rocket, according to Arianespace.

The Vega C rocket, Flight VV22 Mission started with the powerful solid-fuelled P120C first stage booster burning for nearly two-and-a-half minutes, producing a million pounds of thrust to accelerate the rocket into the upper atmosphere. Heading north from the South American coastline, the rocket shed its spent first stage motor casing and fired a second stage Zefiro 40 motor to continue the climb into space. Then the rocket ran into trouble. Telemetry showed a "progressive decrease" of the chamber pressure in the Zefiro 40 solid rocket motor, starting about seven seconds after it ignited, following a good burn by the P120C first stage motor. The chamber pressure suddenly dropped at around T+3 minutes, about two-thirds of the way through the planned burn. Consequently, the range safety officials at the Guiana Space Centre sent a destruct command to the rocket.

This mission was originally supposed to lift off on 24 November, but Arianespace delayed it nearly a month to replace faulty equipment on the rocket, a process that required opening the Vega C's payload fairing at a processing facility in Kourou.

On the 3rd March 2023 the investigation panel concluded that, "The that a component in the motor called a throat insert, made of carbon-carbon material designed to withstand high temperatures, suffered "thermo-mechanical over-erosion" during the launch. That insert regulates the flow of exhaust through the nozzle, and as it eroded the chamber pressure dropped, causing thrust to decrease." The investigation did not find any weakness in the design of the Zefiro motor.

6. Brief description of Orbital Launch Anomalies in 2022

The U.S. Federal Aviation Administration (FAA) observed a record-breaking 92 space missions in 2022, up 33% from the year prior. A majority of launches deliver their expected missions. A brief description of a few that have either never made it to space or failed to deploy their payloads once they got there in 2022, at the global scale, are briefly presented in the paper.

6.1 Launch Anomaly of LandSpace - world's 1st methane-fuelled orbital rocket

On 14th December 2022 LandSpace Technology Corporation launched its Zhuque 2 liquid propellant rocket from Jiuquan in China. This was the world's first orbital launch attempt of a rocket fuelled by methane, beating the likes of SpaceX, Blue Origin, and United Launch Alliance to the pad. [7]

The images from the mission control confirmed that the rocket performed as expected during the first five minutes of the flight. At 5 km/s the second stage most likely suffered an anomaly and failed to accelerate the mission to orbital velocity. At this point in flight, the main engine of the second stage should have shut down, while the four vernier engines would have continued for the final part of the burn. Based on the desired thrust profiles, it appeared that the vernier engines did perform nominal until the second stage cut-off, as the thrust profile did not deviate from the planned profile up to that point. As the vernier engines and the second stage main engine have a lot of shared components, one of these shared parts might have failed, causing an early shutdown of the verniers. [8].

Unconfirmed reports indicate that 14 payloads were on the maiden flight of Zhuque-2. With the rocket not reaching orbit, all of the payloads re-entered the atmosphere and were lost over the Indian Ocean. [2]

6.2 Launch Anomaly of Long March 6A rocket by China Aerospace and Technology Corporation

On 11th November 2022 China Aerospace Science and Technology Corporation launched its second Long March 6A rocket, a first bundle of liquid-fuelled core stage and solid side boosters, successfully sending the Yunhai 3 satellite into its intended orbit. According to Chinese State media it is designed to perform atmospheric and marine environment surveys, space environment surveys, disaster prevention and reduction work, and scientific experiments. Yunhai 3 is now orbiting at an altitude of around 840 km above Earth in a sun-synchronous orbit (SSO), which means it passes over the poles and particular spots on Earth at the same time every day. [2]

The part of the mission that did not go according to plan was the performance of the rocket's upper stage after it released Yunhai 3 into orbit. The used rocket stage suffered a break-up event and is now in more than 50 pieces, at an estimated altitude between 500 to 700 km, adding more space junk to the existing threat of space debris in low Earth orbit [9]. A number of observations have also been made from the ground, illustrating the break-up and fragmentation of the rocket stage. Distinct pieces are tumbling and rotating quickly, creating flash patterns as they catch sunlight. As they are orbiting at an altitude at which there are very few molecules from Earth's atmosphere, it will take many years for the fragments to be brought out of orbit by atmospheric drag. [10]

6.3 Launch Anomaly of Japan's Epsilon rocket

On 11th October 2022 a Japanese Epsilon rocket lifted off from Uchinoura Space Centre for a mission known as Innovative Satellite Technology Demonstration 3.

Initially, everything went smoothly; the solid rocket's first two stages performed as expected, according to commentators during the launch webcast, which was provided by the Japan Aerospace Exploration Agency (JAXA). However, the webcast indicated that anomaly seemed to occur around the time when the third stage was supposed to kick on. As a result, mission controllers activated Epsilon's flight termination system, which destroyed the rocket. [2]

The main satellite that was supposed to reach orbit was RAISE 3 (“Rapid Innovative payload demonstration Satellite 3), a 110 kg craft packed with seven technology-testing payloads. Those payloads included two experimental thrusters, one of which was designed to use water as fuel; a satellite-deorbiting “drag sail;” a deployable power-generating membrane structure that can also serve as an antenna; telecom tech; a high-speed software receiver; and a commercial graphics processing unit, according to EverydayAstronaut.com. [11]
This was the sixth mission for the 24 m tall Epsilon rocket, and its first failure. The five successful lift-offs occurred in September 2013, December 2016, January 2018, January 2019 and November 2021.

6.4. Launch Anomaly of Skyrora space launch attempt

A Skyrora ltd. is a Scottish rocket start-up company, based in Edinburgh, aiming to reach orbit by launching its Skyrora XL vehicle in 2023 from UK. As a step towards this goal, the company completed a key engine test of Skyrora XL’s second stage in August 2022 and described it as the “largest integrated stage test” conducted in the U.K. in 50 years [13].
On 8th October 2022 Skyrora attempted the launch of a sub-orbital rocket from the coast of Iceland. The target was reaching an altitude of 125 km and flying at four times the speed of sound. Conditions at the launch site were tricky with “severe storms and freezing temperatures” in the days before the attempt. [12]
The rocket didn’t reach the heights it aimed for and shut down shortly after lift-off, falling into the Norwegian Sea about a 500 m from the coastal site without harming people or wildlife.
Though the launch didn’t succeed, Skyrora managed to successfully complete some logistical tasks, including packing up and transporting the 11 m rocket and support facilities to the Icelandic site in a shipping container in less than a month. [2]

6.5 Launch Anomaly of Firefly Alpha rocket

On 1st October 2022 Firefly Aerospace made its second attempt to launch the Alpha rocket, lifting off from California’s Vandenberg Space Force Base and successfully inserting three satellites into low Earth orbit. The launch appeared to go well and was a welcome bounce back after Firefly’s first launch of 29 m rocket in September 2021 that ended in failure when one of its first stage engines shut down prematurely. [14]
Although the company had declared the launch a success, the mission was a failure as the payloads had been inserted into lower-than-intended orbits, and the satellites were re-entering the atmosphere already on 5th October, far earlier than desired. [2]

6.6 Launch Anomaly of New Shepard reusable sub-orbital rocket

Blue Origin currently operates two New Shepard vehicle assemblies, both of which are reusable, one for space tourism and one for payload-only flights. Each consists of a rocket and a capsule.
On 12 September 2022 Blue Origin launched the science-only mission. The NS-23 flight was to carry 36 payloads into a suborbital trajectory. This specific flight profile was expected to last for a just few minutes in space and microgravity, also called “zero-g”. However, it did not go as planned. Only, 64 sec after launch, when the vehicle was reaching its maximum dynamic pressure, known as “max q”, an anomaly occurred causing a failure of the booster prompting an in-flight abort of the capsule, at an altitude of 8.8 km. A built-in abort system jettisoned the capsule away from the booster and deployed parachutes that guided it back to Earth. It was recovered safely, but the booster was not recovered. The in-flight abort resulted in the capsule remaining within Earth’s atmosphere. [15]
The rocket is now grounded while the Federal Aviation Administration investigates the failure. [165]
Both prior attempts to launch NS-23, on 31st of August and 7th September of 2022 were scrubbed due to bad weather in West Texas, USA.

6.7 Launch Anomaly of India’s small satellite launch vehicle at first flight test

On the 6th August 2022 India launched a new rocket named the Small Satellite Launch Vehicle (SSLV) from the Satish Dhawan Space Centre on its south eastern coast. The inaugural flight of the34 m rocket had a three-stage configuration with a fourth Velocity Trimming Module (VTM). In its D1 configuration, the rocket was able to lift-off mass of 120t. The rocket carried EOS 02, an Earth observation satellite that weighed 135 kg and AzaadiSAT, a CubeSat payload that weighed 8 kg, developed by Indian students to promote inclusivity in STEM education. The SSLV-D1 was supposed to place the two satellite payloads in a circular orbit of altitude 356.2 km with 37.2° inclination.
Although the launch was going well during the early stages, an anomaly occurred on the fourth and final stage when a sensor issue prevented the upper stage to deliver its two satellite payloads into their intended orbit, meaning they could not be used. [2]
The official explanation by the Indian Space Research Organisation (ISRO) for the mission failure was software malfunction, which detected an accelerometer anomaly during the second stage separation. This caused the rocket navigation to switch from closed loop guidance to an open loop guidance. Although this switch in guidance mode was part of the redundancy built into the rocket’s navigation, it could not salvage the mission. During the open loop guidance mode, the final VTM stage only managed to fire for 0.1s instead of the intended 20s. This led to the two satellites as well as the VTM stage of the rocket being injected into an unstable elliptical transatmospheric orbit of 360.56×75.66 km with an inclination of 36.56°.
According to the Chairman of the Indian Space Research Organisation (ISRO) “The satellites were placed in an elliptical

orbit in place of a circular orbit. The satellites' closest approach to Earth was as close as 46 km, meaning the atmosphere would very quickly drag them back to Earth. ISRO will investigate the issues and prepare for a second test flight of the SSLV rocket." [17]

6.8 Launch Anomaly of iSpace's Hyperbola 1 rocket

On the 25th July 2019 iSpace, the first Chinese private technology development and space launch company, successfully launched the first rocket Y1 into low Earth orbit from the Jiuquan Satellite Launch Centre Gobi Desert, using its Hyperbola 1 solid rocket. However, the following two launches, Y2 and Y5, which took place in February and August 2021, were unsuccessful. [2]

On the 13th May 2022 the fourth launch took the place. Although all seemed well early on according to amateur footage, a confirmation of launch success never came. The Beijing-based Company confirmed the loss of the Y4 rocket and its payloads due to an unknown cause. The payload on this mission was believed to be a high-resolution Earth-imaging satellite for the Chinese Jilin 1 remote sensing constellation.

In October 2022 it was revealed that the failure stemmed from an issue with the attitude control system. With no control over the direction of the rocket, a self-destruct command was activated. [18]

7. Closing remarks

The main objective of this paper was to briefly describe several orbital launch missions where space rockets of different types have either never made it to space or failed to deploy their payloads once they got there. The common denominator for a failure of each individual rocket, according to publicly available information provided by their management and sponsoring teams, is a launch anomaly.

Based on the extremely scarred information regarding some missions and total absence for others reported in this paper, the author will try to make some conclusions based on the knowledge contained in MIRCE Science [1]. Thus:

1. As all mission considered experienced anomalies during the extremely short period of time the most probable mechanisms that caused the launch anomalies have been induced into rockets by humans during: design, production, assembly, transportation or launch actions. As the anomalies occurred on rockets that are designed, made and launched by different companies, located in different countries, it could be concluded that human errors are generic phenomena of the human race.

2. The analysis of failed launches covered in this paper has shown that the majority of them were postponed once, or more times, due to unsatisfactory weather conditions during the launch window available. Thus, it could be concluded that environmental actions did not contributed to the launch anomalies.

3. Finally, it could be concluded that the least probable causes of launch anomalies observed are generated by time-dependent mechanisms, like fatigue, wear, corrosion, creep and similar, which require extensive periods of operation to accumulate the damage. However, if any of components installed have been stored for a very long period of time or have been used on previous missions, there is probability that cumulative damage could cause launch anomaly.

The anomalies addressed in this paper are in agreement with the 5th Axiom of MIRCE Science that states, "Probability of human error in execution of any task is greater than zero". [1]

8. Dedication

Thus paper is inspired and dedicated to the whole Team of Cornwall Spaceport, led by Melissa Thorpe, for their tireless work related to the Virgin Orbit's First UK Satellite Launch in January 2023.

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