Analysis of Teleoperated Robots at Chernobyl

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Max Titov

Spring 2025

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Joshua Earle, Department of Engineering and Society

Introduction

On April 26, 1986, a catastrophic failure during a routine safety test at Reactor 4 of the Chernobyl Nuclear Power Plant in Soviet Ukraine triggered a massive explosion and fire that demolished the reactor building and released enormous amounts of radioactive material into the atmosphere. This event contaminated vast areas across Europe and forced the evacuation of thousands of residents (IAEA, 2021). The disaster exposed critical vulnerabilities in nuclear safety protocols and emergency response mechanisms.

After the crisis, Soviet authorities attempted to manage the fallout using teleoperated robots designed to work in highly radioactive conditions. However, these early robotic systems proved to be ineffective at the Chernobyl site. Their technical shortcomings, including sensor malfunctions and inadequate radiation shielding, rendered them unreliable, forcing the government to depend instead on thousands of workers, who were called “liquidators.” They were exposed to lethal doses of radiation and bore the brunt of the cleanup efforts. In the end, only ten percent of the cleanup was done by robots; the rest was done by humans (Anderson, 1990).

The failure of these teleoperated robots highlights a broader breakdown within the sociotechnical network that included not only technical components but also human operators and institutional frameworks. Miscommunications, lack of proper coordination, and bureaucratic issues compounded and even led to technological limitations, ultimately leading to a greater human cost of the disaster. This tragedy has reshaped global nuclear safety standards and emergency response strategies, emphasizing that future crisis management must integrate robust operator training, effective communication protocols, and comprehensive institutional support. By learning from these failures, policymakers and engineers can work together to develop more resilient systems that better safeguard both human lives and the environment in high-risk situations (Williams, 2021).

In this paper, I examine how the interactions between technology, people, and institutions shaped the outcomes of teleoperated robots used in the Chernobyl cleanup. By examining the relationships among the robotic technology, the operators controlling them, and the institutional frameworks that directed their use, I identify lessons for improving both robotic systems and emergency management protocols. Understanding these interactions is essential for preventing failures in future high-risk situations. The central argument is that the failures with Chernobyl's teleoperated robots were not solely technical but also resulted from breakdowns in the sociotechnical network.

To frame this investigation, I apply Actor-Network Theory (ANT), which provides a useful lens for examining the complex relationships among human and non-human actors in the system. ANT allows me to trace how engineers, operators, and regulatory institutions interacted throughout the design, deployment, and operational phases of the teleoperated robots. By viewing these robotic systems as part of a broader sociotechnical network, I gain a broader understanding of the factors that led to their ultimate failure. My methods include a review of archival documents, technical descriptions, and official reports, supplemented by interviews with experts in robotics and primary sources. The results reveal that, while significant technical challenges existed, the primary issues were rooted in the failure of the network of actors. Additionally, failures within the network directly lead to technical challenges of the robots.

Finally, I explore implications from this case study for future crisis response to demonstrate that ensuring the safety and effectiveness of teleoperated robots in high-risk environments requires attention to both technical and sociotechnical factors of robotics development. Future research should continue to explore these interactions to develop strategies that better integrate technology, human expertise, and institutional oversight. Drawing lessons from Chernobyl, policymakers and engineers can work together to create systems that fit into the network of human and institutional interactions.

Chronological Report

The immediate hours following the Chernobyl disaster on April 26, 1986, were characterized by chaos and uncertainty. As radiation levels soared to lethal levels, estimated up to 10,000 roentgens/hour near the debris, the Soviet leadership faced the challenging task of containing the disaster while minimizing human exposure to radiation. Initial firefighting efforts were conducted by personnel who lacked proper protective equipment, resulting in severe radiation exposure and numerous casualties (Roberts, 2020).

Within days of the disaster, Soviet authorities began deploying remotely operated machinery to limit human exposure to radiation. Marshal Sergey Akhromeyev reported that "remote control equipment (which failed practically immediately because of high levels of radioactivity and had to be replaced with 'biorobots' - Soviet soldiers) has arrived," indicating that the first teleoperated robots were deployed almost immediately but quickly succumbed to the intense radiation (Yaroshinskaya, 1992). By April 30, the Soviet military had already begun mobilizing chemical troops to manually clear the most radioactive debris after the initial robots failed.

The technical specifications of these first robots remain somewhat unclear, but their failure highlighted a critical gap in the Soviet crisis response capabilities. By May 1986, Soviet authorities were actively seeking more advanced robotic solutions both domestically and from abroad. The West German MF-3 robot, a tracked telemanipulator from KFA Jülich, was deployed from May 25, 1986. The MF-3 was designed with a 7-degree-of-freedom manipulator arm and cameras specifically for nuclear emergencies, but with a critical limitation: it required a tethered control system connected via a 100-meter cable. This design choice proved problematic in the unpredictable environment of Chernobyl, where the cable frequently snagged on debris (Bishop, 1987).

Despite these challenges, the MF-3 managed to perform some useful work, conducting radiation surveys inside the turbine hall and removing debris from the roof of Unit 3, next to the destroyed Unit 4. It successfully picked up approximately 300 pieces of graphite and several fuel channel tubes, operating via tether through building corridors and even using an elevator to reach the roof. However, by mid-June, the robot's electronics began failing intermittently due to radiation exposure. On June 15, 1986, while working on the "A" section of the roof, the MF-3's onboard dosimeter and cameras successfully recorded radiation levels and mapped hot spots, but shortly thereafter, multiple malfunctions occurred. The technical failures of the MF-3 showcased challenges faced by all robotic systems at Chernobyl. Voltage regulators burned out, a drive motor failed, and control relays stopped functioning, requiring frequent repairs by the Kiev Institute of Automatics. The robot eventually accumulated about 100 hours of operation across 25 remote-controlled shifts before becoming too unreliable for further use (Bishop, 1987).

In parallel with these foreign robot deployments, Soviet engineers were rapidly developing domestic solutions. By the end of May, they had begun adapting space technology for use in the cleanup effort. The STR-1 special transport robots, essentially modified six-wheeled lunar rovers, were built by soviet company VNIITransmash within weeks of the accident. This robot featured a 2-meter bulldozer blade and was designed to push debris, with a theoretical range of 500 meters by radio control (Bishop, 1987).

By July 1986, the Soviets had also deployed another imported machine, the MF-2 robot, nicknamed "Joker", a West German police robot adapted for Chernobyl. On July 22, 1986, the Joker was placed on the roof inside a special container and began pushing radioactive debris with a small bulldozer blade. Unlike the MF-3, the Joker featured wireless radio control, which theoretically offered greater freedom of movement. However, the Joker's performance was disappointing. It operated for only about twenty minutes before its batteries needed recharging. More significantly, on July 26, 1986, the Joker suddenly lurched 15 meters on its own and crashed into a ventilation duct support. Investigators concluded that intense radiation caused "irradiation of the robot's electronic system" (Bishop, 1987, 4). By the end of July, one of Joker's camera feeds had failed, and communication was increasingly unreliable (Bishop, 1987).

By early August 1986, the two STR-1 units that had been developed by Soviet engineers were delivered by helicopter onto the reactor complex roofs. These robots were theoretically better suited to the Chernobyl environment, given their design heritage from Soviet space program technology. However, they too encountered significant difficulties. The uneven terrain, with piles of rubble, twisted metal, and holes in the roof, proved challenging for the robots' wheel traction and suspension systems ("Chernobyl X," 2021). More critically, the intense gamma radiation penetrated the robots' electronics, causing control signals and onboard circuitry to fail. In response to these challenges, operators were forced to retrofit a cable control system onto the STR-1 robots as a backup, which severely limited their mobility (Bishop, 1987). Despite some successful runs removing bitumen and debris, the STR-1 robots required frequent retreats for repairs. By September, both units were experiencing significant operational difficulties ("Chernobyl X," 2021).

During this same period, the Soviets also deployed a Japanese made Komatsu D-355W amphibious bulldozer, a 60 ton remote controlled machine known for its ability to work underwater. This massive machine was tasked with pushing radioactive soil and wreckage but "inevitably could not withstand the extreme level of radiation... and quickly broke." Its electrical systems and hydraulics failed when subjected to the approximately 10,000 R/hour environment found in parts of the site (Husseini, 2018).

By September 1986, it had become clear that the teleoperated robots could not complete the cleanup task within the required timeframe. Soviet leaders faced increasing pressure to complete the decontamination and seal the reactor before winter set in. In response, Colonel-General Nikolai Tarakanov and other leaders organized thousands of reservists and cadets into radiation cleanup squads. These men, dubbed "biorobots," were tasked with completing the work that the machines "could not do" (Roberts, 2020, 312). Working in relays of only 1-2 minutes per person, they dashed onto the roof, shoveled high-dose debris, and threw it into the ruins of Unit 4 below. Photographs from this period show teams in makeshift lead armor working amid the wreckage on the roof. In some hyper-hot spots, exposure time was limited to just 40 seconds before a worker would reach a lifetime radiation dose. By October 1986, through this grueling manual effort, the roof was finally cleared of the most dangerous debris. On November 30, 1986, the concrete and steel Sarcophagus enclosing Reactor 4 was completed, largely due to the sacrifices of these human liquidators rather than the robotic systems that had been expected to do the job (Roberts, 2020).

In the aftermath of the cleanup, Soviet authorities quietly sought to obtain more advanced Western robotics for monitoring and further cleanup work. In 1987, they reached out to Dr. William "Red" Whittaker, the American roboticist who had designed robots for the Three Mile Island cleanup, hoping to purchase identical units for Chernobyl. Whittaker and colleagues formed a company to supply these robots, but the sale was ultimately blocked by U.S. technology export limitations in force during the Cold War ("U.S. technology aids Chernobyl assessment", 1999). Throughout the late 1980s, Soviet teams and international partners continued to develop robots for surveying the sealed reactor and preparing for future waste removal. As Yuri Semiolenko, the Soviet official in charge of decontamination at Chernobyl, later summarized: the challenge was to clear 100 tons of deadly debris, and "unfortunately, we were not able to decontaminate the roof without using mostly manual labour" (Husseini, 2018).

Actors of the Network

Actor-Network Theory provides a useful framework for understanding the failures of teleoperated robots during the Chernobyl cleanup. ANT argues that technological systems are not isolated artifacts but are part of a complex network of interactions among human, technical, and institutional actors. Key to ANT is the idea that the connections and interactions among the various actors determine the network's relative strength and whether it succeeds or fails (Cressman, 2009). By examining the teleoperated robots within this broader sociotechnical network, we can see how technical shortcomings were closely intertwined with human, organizational, and external influences, leading to their overall failure.

The teleoperated robots deployed at Chernobyl represent primary non-human actors in the network. The Soviet Union used about 60 teleoperated robots during the Chernobyl cleanup, including STR-1 units, West German MF-2 and MF-3 robots, and heavy bulldozers. These machines struggled to operate in the harsh environment. Rough terrain and rubble made movement difficult, and high radiation quickly damaged their electronics. The STR-1s couldn't navigate debris and became useless within months. The MF-3's cable control system snagged easily, and it broke down often. The MF-2, though wireless, needed clear signals and failed under high radiation. All robots faced serious reliability issues that limited their use at the disaster site (Bishop, 1987).

These technical limitations represent a failure in the translation of requirements between actors in the network. The robots were designed based on incomplete or inaccurate information about the environmental conditions they would face, resulting in a mismatch between their capabilities and the demands of the situation. This misalignment of actors' capabilities and expectations set the stage for the broader sociotechnical failure that followed.

The Chernobyl cleanup effort involved many human actors, including robot operators, engineers, military personnel, and political decision-makers. Their interactions with robotic systems and each other played a crucial role in the cleanup process. Operator training and experience emerged as a significant limitation, with the Soviet Union lacking experienced nuclear robot operators in 1986. Soldiers and technicians were tasked with controlling devices like STR-1 and Joker with minimal practice leading to potential operational errors such as rovers getting stuck in challenging positions ("Chernobyl X," 2021).

Engineers faced immense challenges in designing and maintaining robots under extreme time pressure and limited resources. The Mobile Vehicle Engineering Institute had only two months to adapt the Lunokhod design for the STR-1, and they were forced to use commercial electronics due to the unavailability of radiation-hardened chips (“STR-1 Specialized Transport Robot,” 2012). The Kiev Institute of Automatics spent considerable time repairing robots, replacing burned-out boards and improvising lead glass shielding (Bishop, 1987). Political decision-makers also significantly influenced the robot deployment, initially hesitant to send men onto the roof to avoid national embarrassment, but later mandating a rapid cleanup by a set date, which ultimately led to the deployment of human "biorobots" to complete the task (“Chernobyl X,” 2021).

These technical limitations represent a failure in the communication of requirements between actors in the network. The robots were designed based on incomplete or inaccurate information about the environmental conditions they would face, resulting in a mismatch between their capabilities and the demands of the situation. This misalignment of actors' capabilities and expectations led to the broader sociotechnical failure that followed.

Finally, the institutional actors in the Chernobyl cleanup network included the Soviet government, military, and scientific organizations, as well as international entities affected by the disaster and Cold War politics. These institutional actors shaped the broader context in which the robot cleanup effort took place.

The Soviet bureaucracy, with its culture of secrecy and rigid hierarchies, significantly impeded effective crisis response. The Soviet leader Gorbachev waited 18 days to speak publicly, even as Western media and foreign governments reported rising radiation. Even though Gorbachev was pushing the policy of “glasnost” (openness) to provide more transparency in Soviet media, reporting on Chernobyl was done the traditional, secretive, way (Daniloff, 1992, 122). Leonid N. Dobrokhotov, a high Communist Party official, stated “we had to play down the catastrophe, to prevent panic among the people, and to fight against what was then called bourgeois falsification, bourgeois propaganda and invention” (Daniloff, 1992, 122). In many cases, this censorship “actually encouraged [panic] by speculative information from abroad and by the failure of Soviet authorities to make the latest facts available at the scene” (Daniloff, 1992, 127). One official commented during a press conference that “the evacuation had been delayed needlessly for thirty-six hours,” which put local residents at greater risk of radiation exposure (Daniloff, 1992, 128). The Soviet Union was pushing to be more open during this time period, but the untimely and secretive response to the disaster suggests the opposite.

These institutional actors created a network environment that was not conducive to effective robot deployment and operation. The culture of secrecy led to miscommunication and misaligned expectations. The fragmented organizational structure hindered coordination and information sharing. These institutional factors interacted with the technical and human factors to create a perfect storm of failure conditions.

Analysis of the Network

Actor-Network Theory emphasizes the importance of successful interactions between actors, which is the process by which actors' interests, capabilities, and expectations are aligned to create a functioning network. In the Chernobyl cleanup, several critical misalignments and breakdowns in these translations led to the failure of the robot cleanup effort.

One critical misalignment occurred in the miscommunication of environmental conditions to robot designers. The extreme radiation levels at Chernobyl far exceeded what the robots were designed to withstand. This was particularly evident in the case of the West German MF-2 "Joker" robot, which was designed for radiation levels of up to 2,000 R/hour but was exposed to fields much greater (Charleston, 2019). The Soviets “refused to tell the West Germans how much radiation was on that roof … it was 600 percent or 700 percent more than [the robot] could handle” (“Chernobyl X,” 2021). This misalignment was compounded by the Soviet authorities' reluctance to fully disclose the severity of the situation. Without a proper exchange of information, the “Joker” robot was destined to fail before it was even created.

Another breakdown occurred in the translation between operators and robots. The lack of trained operators meant that those controlling the machines were often learning on the job, which led to operational errors. Unlike at Three Mile Island, where U.S. engineers had experience with robotic systems, Soviet personnel at Chernobyl had little to no prior training in teleoperation. As a result, many operators struggled with basic tasks under high-stress conditions (Anderson, 1990). This problem was made worse by the stressful working environment. Operators were working in improvised shielded positions, sometimes inside damaged buildings, knowing that if their machines failed, they could be called in next to complete the task manually (“Chernobyl X,” 2021). The interview with engineer Alexei Ananenko also confirms that the technical staff and liquidators faced enormous pressure and uncertainty during the response effort (Ex Utopia, 2021). That pressure, combined with the physical discomfort of working in hot, heavy protective gear, contributed to mental fatigue and mistakes. For instance, the transcription of Legasov’s tapes notes that “the intermittent changes in the composition of the [Government Commission] led to a constantly changing plan of work,” further leading to disorganized responsibilities (Timofeyev, 2020). The broader emergency response suffered from miscommunication and a lack of coordination, which made it difficult for operators to adapt to technical failures as they occurred (Williams, 2021). As shown through these examples, training and proper working conditions are key to successful human operation of robots.

A third breakdown involved political tensions between the Soviet Union and the United States, which complicated the Chernobyl cleanup by restricting the exchange of valuable technical knowledge. Allowing international collaboration could have introduced better technology and robust safety protocols. Each side guarded its advancements as strategic assets, preventing the incorporation of proven Western robots into the Soviet cleanup efforts (Anderson, 1990). Teleoperated robots designed by Carnegie Mellon University helped to successfully clean up the nuclear debris of the Three Mile Island nuclear disaster, 7 years prior to the Chernobyl disaster. The Soviet government tried to buy these robots, "but the sale was blocked by U.S. technology export limitations in force at that time" ("U.S. technology aids Chernobyl assessment", 1999). This guarded approach not only prevented the use of proven teleoperated robots at the Chernobyl site but also deepened the technological divide between the Soviets and the United States. The secrecy surrounding nuclear technology during the Cold War created an environment where every technical improvement was protected, thus hindering international cooperation. As a result, the Soviet response was forced to rely on inadequately tested and rushed equipment, ultimately increasing the difficulties of the cleanup. Yuri Semiolenko concisely describes this breakdown as "bureaucratic bungling rather than any desire for efficiency that restricted the use of foreign robots" (Anderson, 1990).

In defending this argument, it is essential to counter alternative interpretations that focus solely on technical deficiencies. While it is true that the teleoperated robots suffered from sensor issues, inadequate radiation shielding, and mechanical malfunctions, these problems cannot be fully understood without considering the broader sociotechnical context. A purely technical analysis would overlook how miscommunications, shifting institutional priorities, and political pressures created an environment that led to oversights in the technological design.

This analysis demonstrates that the failures of the teleoperated robots during the Chernobyl cleanup were largely caused by the sociotechnical network. Using Actor-Network Theory as a lens, we can see that the breakdowns were not confined to the technology itself but were also a result of poor communication among human operators, misaligned and often secretive institutional protocols, and external pressures such as harsh environmental conditions and political isolation. Both technical and sociotechnical failures played critical roles in the ineffectiveness of the robotic systems. This integrated perspective is crucial for informing future crisis responses. By learning from past mistakes within the sociotechnical network, policymakers and engineers can work together to design more effective systems for disaster response in the future.

Discussion

Understanding the failures of teleoperated robots at Chernobyl provides important lessons for future crisis responses. The analysis of this event shows that technical problems were not the only issues; the failures were deeply embedded in the broader sociotechnical network. This network included not only the robotic systems and their sensors, but also the human operators, the institutions that supported them, and external factors such as political pressures and extreme environmental conditions. Recognizing the importance of these interactions is essential for improving how we respond to crises today.

The significance of studying these sociotechnical interactions is the need to create more resilient and effective disaster response systems. At Chernobyl, the breakdown in communication between engineers, technicians, and institutional bodies led to delays and further exposure of workers to radiation. The lessons learned from this tragedy underscore that future crisis management must integrate both technical innovation and strong organizational practices. For example, understanding how decisions were made and how information was shared during the Chernobyl cleanup can help modern emergency managers design better communication protocols and ensure that operators are properly trained to use complex systems.

The results suggest a number of implications for current and upcoming robotic systems. Modern teleoperated robotics must be supported by improved operator training. Workers need to understand not only how to operate the machines but also how to respond when systems fail. This means that training programs should include simulations of equipment malfunctions and scenarios that require quick decision-making under pressure. In addition, communication protocols between field operators and institutional leaders must be streamlined. Clear communication channels can help reduce delays in decision-making and prevent the kind of miscommunication that worsened the Chernobyl disaster. Institutions and regulatory bodies must also provide robust support, ensuring that all elements of the network are aligned. This includes not only setting safety standards but also establishing plans for when unforeseen issues arise. Technical systems should be designed with redundancy and fault tolerance in mind, while human operators should have access to real time data and decision making tools. Moreover, institutions should create an environment where information flows freely between all parties. Such an approach can reduce the risk of similar failures in the future by ensuring that technical innovations are supported by a well functioning sociotechnical network.

Future research should delve deeper into the specific network interactions that occurred during the Chernobyl cleanup. Detailed case studies that trace communications between engineers, technicians, and government agencies could provide valuable insights into how these interactions influenced the outcome. Researchers should also compare the successes and failures of different types of teleoperated robots used in various crises. Another research avenue is looking into the teleoperated robots that helped with the surveillance and cleanup of the more recent Fukushima nuclear disaster. By examining similar systems in other high-risk environments, scholars can identify best practices and common pitfalls that may not be evident when focusing solely on technical aspects.

Moreover, there is a need to explore how external influences, such as political tensions and media coverage, affected the deployment and operation of robotic systems during the disaster. For example, archival evidence indicates that political pressures prevented the sharing of advanced technology between the Soviet Union and Western nations (Williams, 2021). Future studies might investigate how such external factors can be mitigated or leveraged to improve response efforts. Research could also examine new forms of teleoperated robotics, looking into recent advancements in sensor technology and artificial intelligence, to determine if modern systems are better equipped to handle extreme environments. In today's age of artificial intelligence, a transparent exchange of information is vital for safely advancing the technology for the benefit of humanity.

Conclusion

The failures of the teleoperated robots at Chernobyl were not merely technical faults but were significantly influenced by breakdowns in the sociotechnical network. Miscommunication between designers and operators, Soviet secrecy, and political pressures all shaped the environment in which these robots were deployed. Technical limitations were real, but they were compounded by a lack of operator training, ineffective decision making, and an unwillingness to adapt when systems failed. This resulted in the reliance on human "liquidators" or "biorobots" who were exposed to life threatening radiation to complete the tasks the robots could not.

Actor-Network Theory helps explain how these failures were rooted in the fragile connections among people, technology, and institutions. The robots did not fail in isolation; they failed within a poorly coordinated network that could not respond flexibly to crisis. Had there been more open communication, clearer responsibilities, and better collaboration across institutional boundaries, many of the failures might have been mitigated or avoided entirely. By learning from these past failures, we can work towards developing more integrated, robust crisis response systems. Ensuring that technical, human, and institutional components are effectively aligned will be key to preventing future disasters and protecting human life during high-risk disasters.

References

Anderson, C. (1990, January 19). *Soviet official admits that robots couldn't handle Chernobyl cleanup*. The Scientist Magazine®. https://www.the-scientist.com/soviet-official-admits-that-robots-couldnt-handle-chernobyl-cleanup-61583

Bishop, R. X. (1987, January 24). *Robots of Chernobyl*. Academia.edu. https://www.academia.edu/102461234/Robots_of_Chernobyl_Draft_Translation

Charleston, L. (2019, July 6). *The Claw of Chernobyl*. NZ Herald. https://www.nzherald.co.nz/world/the-claw-of-chernobyl-most-dangerous-thing-in-the-exclusion-zone/UHRVMAMFU53AUOP43SAD5JMQYQ/?c_id=2&objectid=12247342

Chernobyl Robots. Chernobyl X. (2021, December 6). https://chernobylx.com/chernobyl-robots/

Clarion Energy Content Directors. (1999, July 1). *U.S. technology aids Chernobyl assessment*. Power Engineering. https://www.power-eng.com/nuclear/us-technology-aids-chernobyl-assessment/

Daniloff, N. (1992). *Chernobyl and Its Political Fallout: A Reassessment*. Demokratizatsiya. https://demokratizatsiya.pub/archives/12_1_12_1_DANILOFF.pdf

Hero of chernobyl: An Interview with engineer Alexei Ananenko. Ex Utopia. (2021, April 26). https://www.exutopia.com/chernobyl-interview-alexei-ananenko/

Husseini, T. (2018, December 4). *Cleaning up nuclear waste: A history of robotics development*. Power Technology. https://www.power-technology.com/features/cleaning-up-nuclear-waste-robotics/?cf-view

IAEA. (2021, April 23). *The 1986 Chornobyl Nuclear Power Plant Accident*. International Atomic Energy Agency. https://www.iaea.org/topics/chornobyl

Roberts, W. C. (2020, January 31). *Facts and ideas from anywhere*. National Library of Medicine. https://pmc.ncbi.nlm.nih.gov/articles/PMC7155967/pdf/ubmc-33-02-1725731.pdf

STR-1 Specialized Transport Robot. Shvachko. (2012, May 23). https://shvachko.net/?p=836&lang=en

Timofeyev, Y. (2020, August 10). *Tape 3 side A*. Tape 3 Side A. https://legasovtapetranslation.blogspot.com/2019/10/tape-3-side-a.html

Williams, M. (2021, April 26). *Unsealed Soviet archives reveal cover-ups at Chernobyl plant before disaster*. Reuters. https://www.reuters.com/world/unsealed-soviet-archives-reveal-cover-ups-chernobyl-plant-before-disaster-2021-04-26/

Yaroshinskaya, A. (1992). *CC CPSU Politburo Operational Group Session protocol #2*. National Security Archive. https://nsarchive.gwu.edu/document/19494-national-security-archive-doc-7-cc-cpsu