# Starship Orbital Test Flight 1
# Final Mishap Investigation Report

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Written by: Shana Diez
Reviewed by: Rachel Sage, Pamela Berkowitz, Derek Williams

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(b) (4) [redacted]

# Executive Summary

SpaceX Starship Super Heavy vehicle (Booster 7 and Ship 24) was launched from SpaceX's launch site in Boca Chica, Texas at 13:33:09.122 UTC on April 20, 2023. (b) (4), (b) (3) (A) [redacted]

Shortly after liftoff, video evidence indicates that a significant structural failure of the launch pad deck foundation occurred. This failure resulted in bulk soil displacement below and around the launch mount sending a considerable amount of sand and debris into the air. (b) (3) (A) [redacted]

As the vehicle continued on its flight path, it successfully cleared the launch tower and proceeded downrange. (b) (3) (A) [redacted].

(b) (3) (A), (b) (4) [redacted]

(b) (3) (A) [redacted]

(b) (3) (A) [redacted]

(b) (3) (A), (b) (4)

[redacted]

This rule violation resulted in the firing of the Autonomous Flight Safety System (AFSS) destruct command on both the Super Heavy Booster and Starship's independent AFSS. All 4 destruct charges (2 on each vehicle stage) successfully fired, and all 4 main tanks were successfully opened as a result. At T+237.474s the vehicle exploded in mid-air. (b) (4), (b) (3) (A)

[redacted]

(b) (4)

[redacted]

(b) (4), (b) (3) (A)

| [redacted] | [redacted] | [redacted] |
|---|---|---|
| [redacted] | [redacted] | [redacted] |
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| [redacted] | [redacted] | [redacted] |

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| (b) (4), (b) (3) (A) | [redacted] | [redacted] |

[redacted]

The Starship and Super Heavy program is focused on a new launch vehicle that is still in the early stages of development by SpaceX. With the exception of the AFSS system and Starship software, the Starship program does not yet use SpaceX standard processes for design, build, and mission assurance. (b) (4) [redacted]

# 1. Purpose

Starship Orbital Test Flight 1 (OTF-1) was launched under Federal Aviation Administration (FAA) Commercial Space Transportation License VOL 23-129 on April 20, 2023 at 13:33:09 UTC. (b) (3) (A) [redacted] The vehicle suffered several engine and vehicle system failures resulting in a mission rules violation at 13:36:16 UTC, triggering the automated flight termination system. The vehicle exploded midair and was lost.

After the mishap, Space Exploration Technologies Corp. (SpaceX) initiated an investigation (b) (4) [redacted]

# 2. Test Overview

## 2.1 Test Article

SpaceX built Starship Super Heavy at the SpaceX production facility in Boca Chica, TX. This prototype vehicle had previously gone through a series of pre-flight operations before OTF-1. Starship Super Heavy is comprised of two stages: Starship Super Heavy Booster (Booster 7 or B7) and Starship (Ship 24 or S24). Booster is comprised of a main liquid oxygen (LOx) tank, a main liquid methane (LCH4) tank, a liquid oxygen landing tank, thirty-three Raptor sea-level engines, grid fins, sub-assemblies, and a flight termination system. Ship is comprised of a liquid oxygen (LOx) tank and header tank, a liquid methane (LCH4) tank and header tank, an aft skirt, three Raptor sea-level engines, three Raptor vacuum engines, a nosecone, flaps, sub-assemblies, and a flight termination system. An overview diagram is shown in Figure 1.

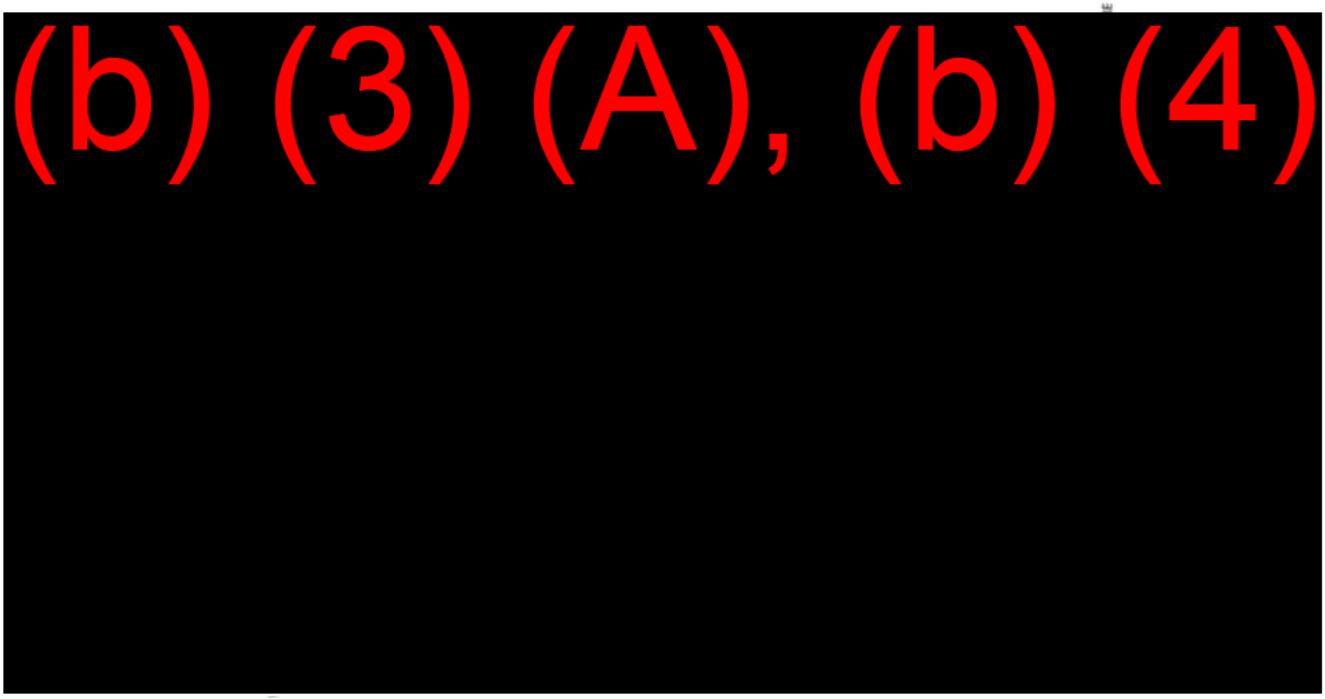


**Figure 1: Starship Super Heavy vehicle overview.**

(b) (4) [redacted]

(b) (3) (A), (b) (4)

[redacted]

(b) (4) [redacted]

(b) (3) (A), (b) (4)

(b) (4) [redacted]

### 2.2 Time Standards

Unless otherwise specified, all event time references in this report are relative to Booster 7 t-time=0 and denoted as T+/-[n], which is a deterministic time for flight software commands and corresponds to the initiation of the quick disconnect (QD) retract sequence. T-0.000s corresponds to 2023-04-20 13:33:09.122 UTC.

(b) (3) (A), (b) (4) [redacted]

(b) (3) (A), (b) (4) [redacted]

## 3. B7/S24 Pre-flight Test Campaign Timeline

The combined Booster 7 and Ship 24 vehicle underwent the system-level ground test operations (b) (4) [redacted]

(b) (3) (A), (b) (4) [redacted]

[redacted]

(b) (4), (b) (3) (A) [redacted]

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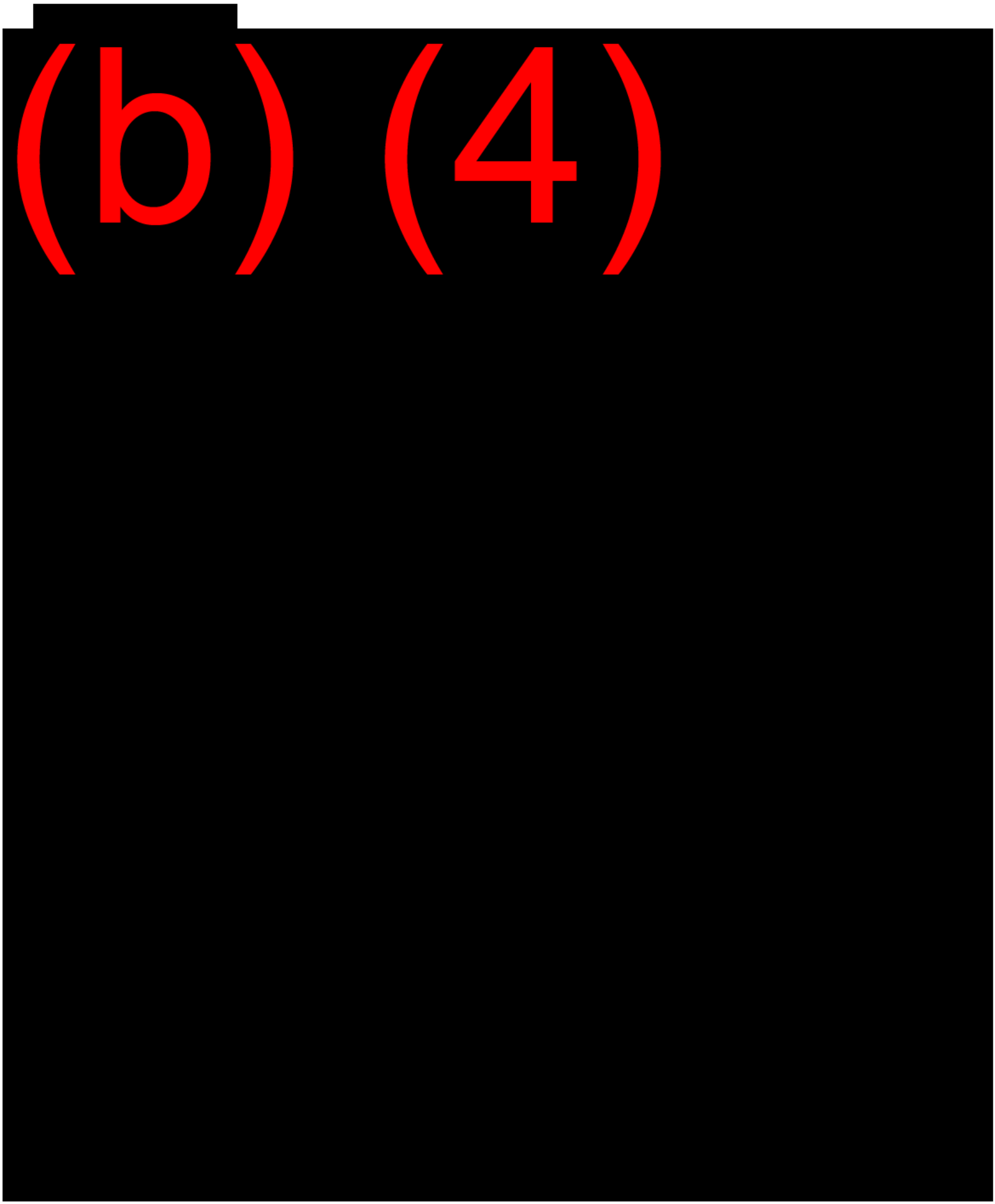
(b) (4)

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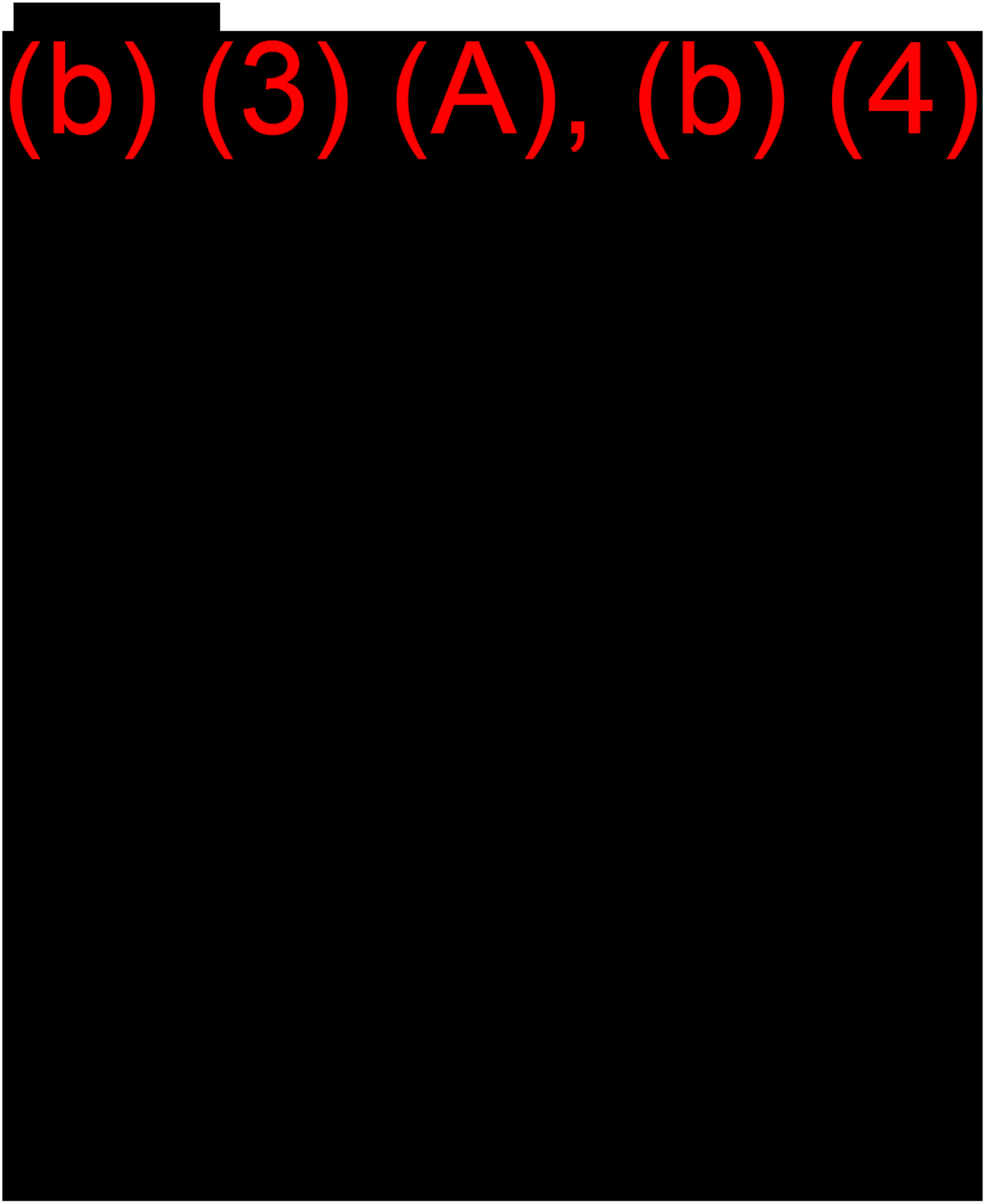

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| [redacted] | [redacted] | [redacted] |
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| [redacted] | [redacted] | [redacted] |

(b) (3) (A), (b) (4)

SpaceX Starship Super Heavy vehicle (Booster 7 and Ship 24) was launched from SpaceX's launch site in Boca Chica, Texas at 13:33:09.122 UTC on April 20, 2023. (b) (3) (A)

[redacted]

(b) (3) (A)

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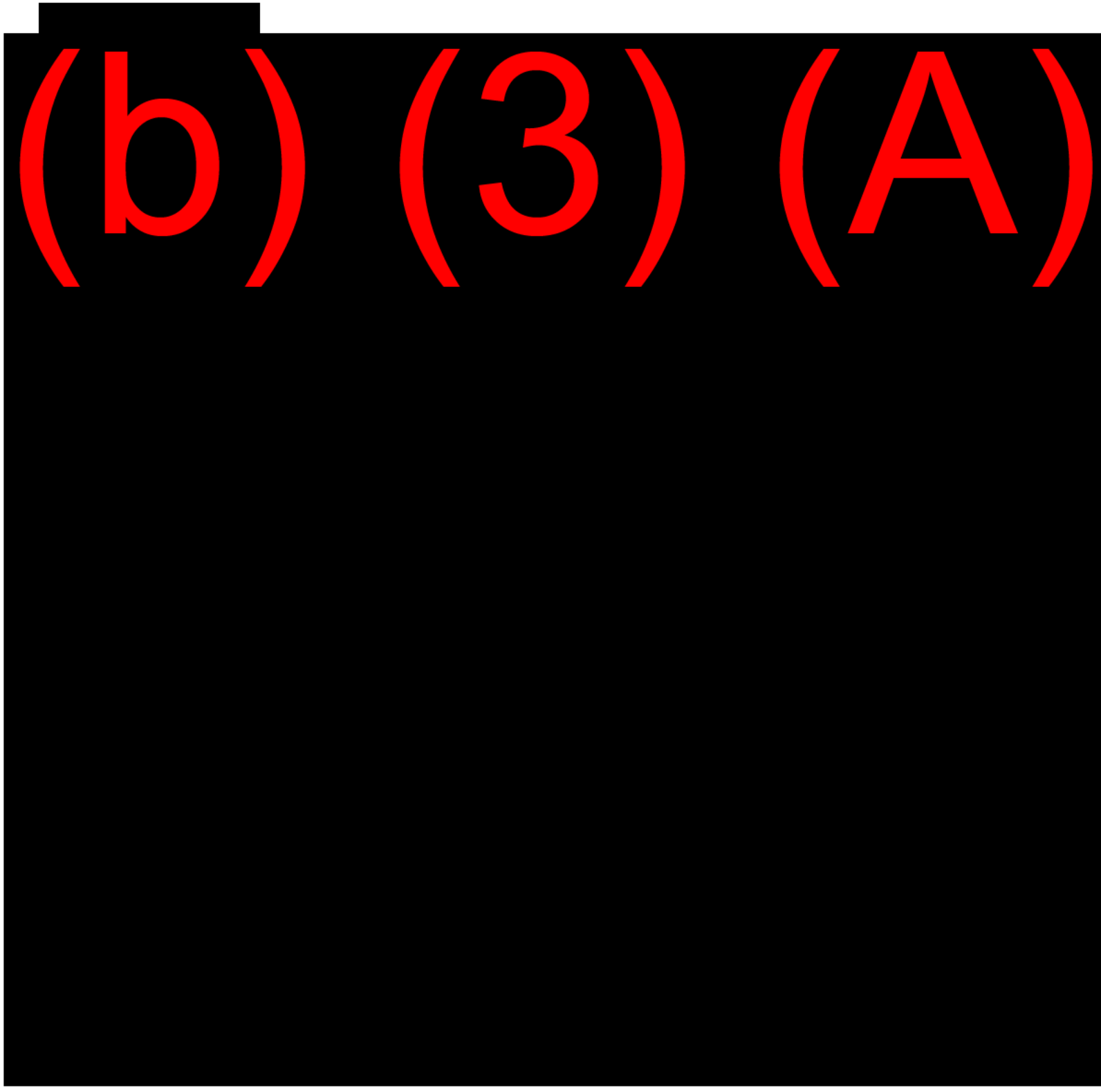
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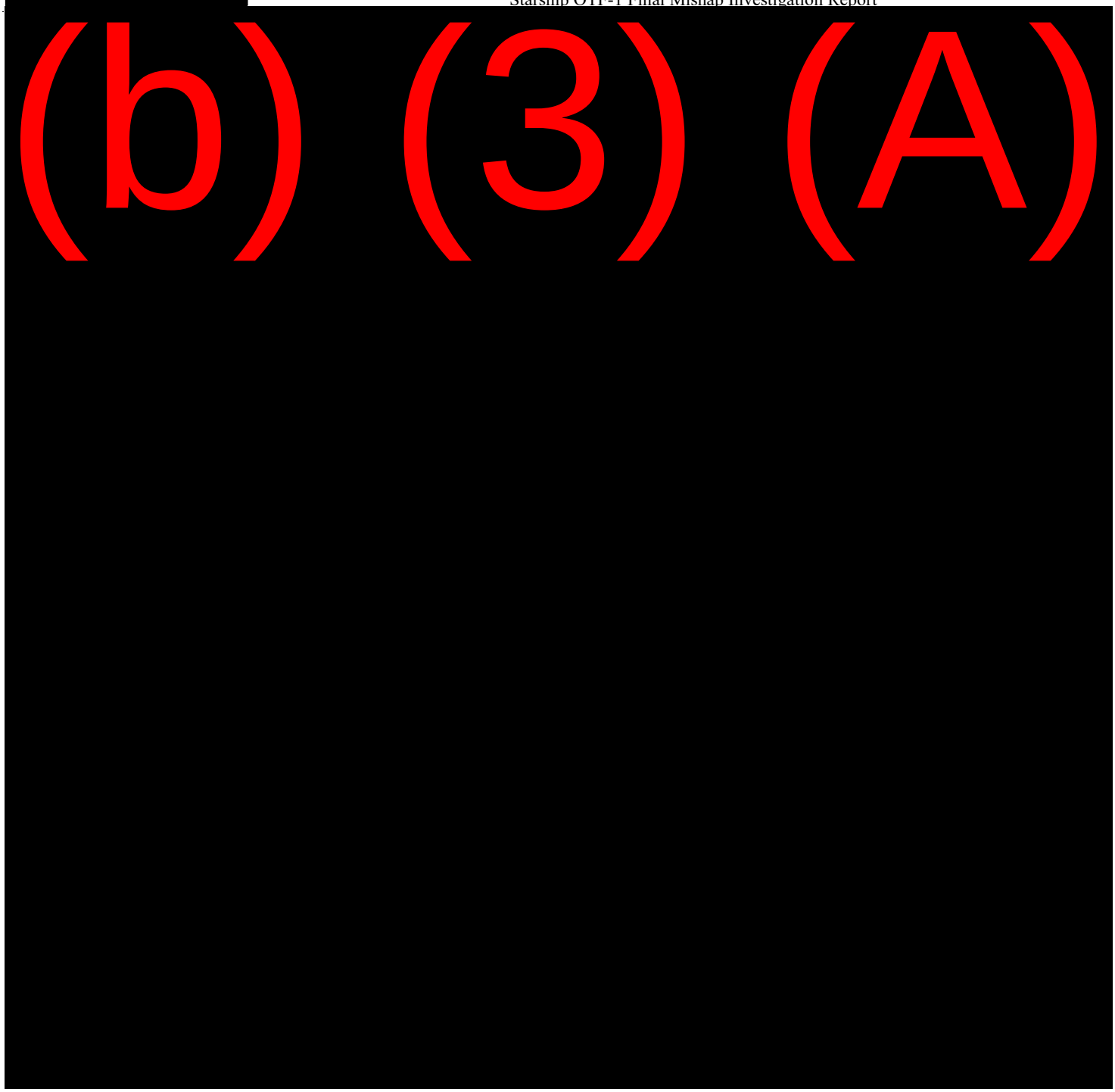

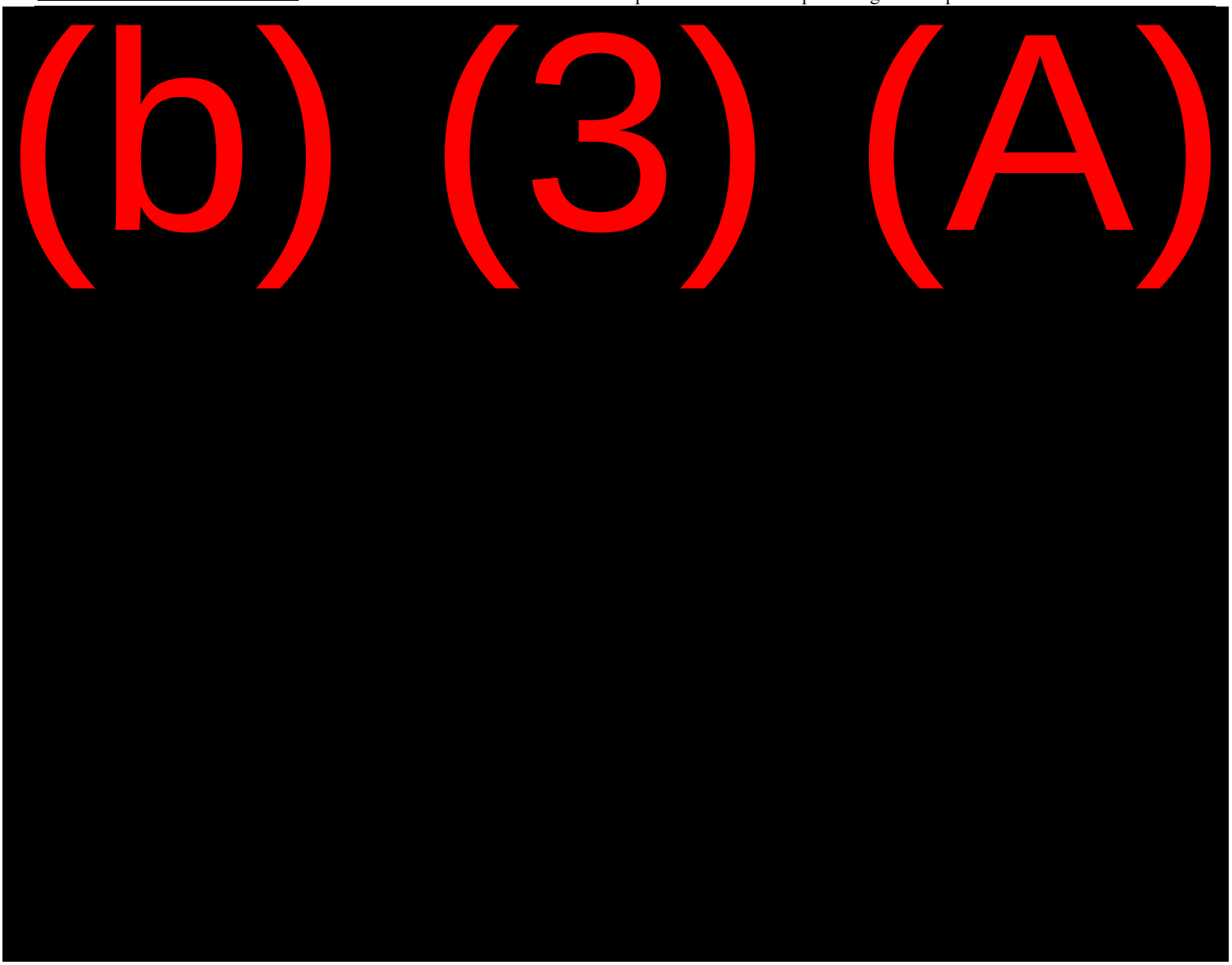

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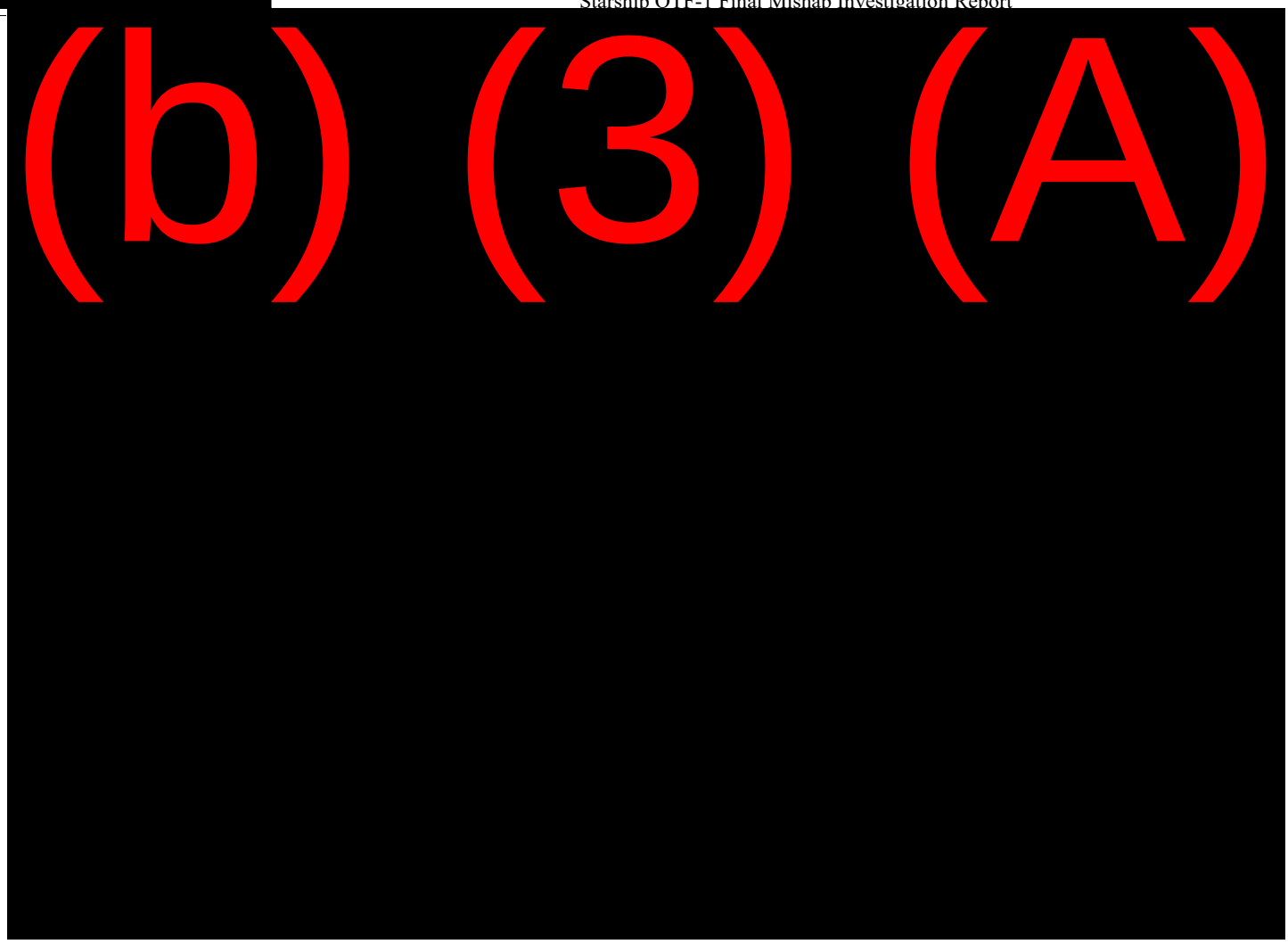

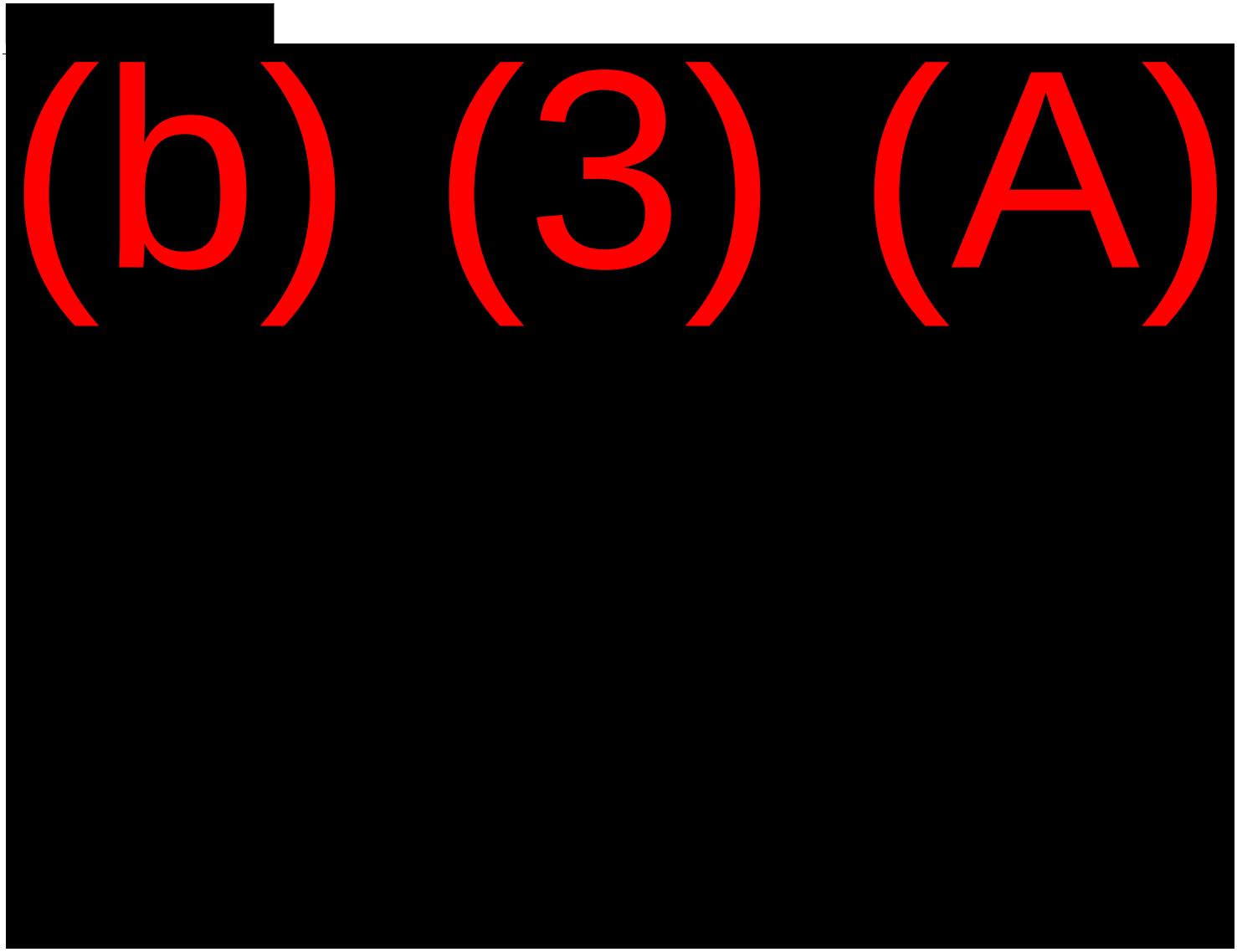

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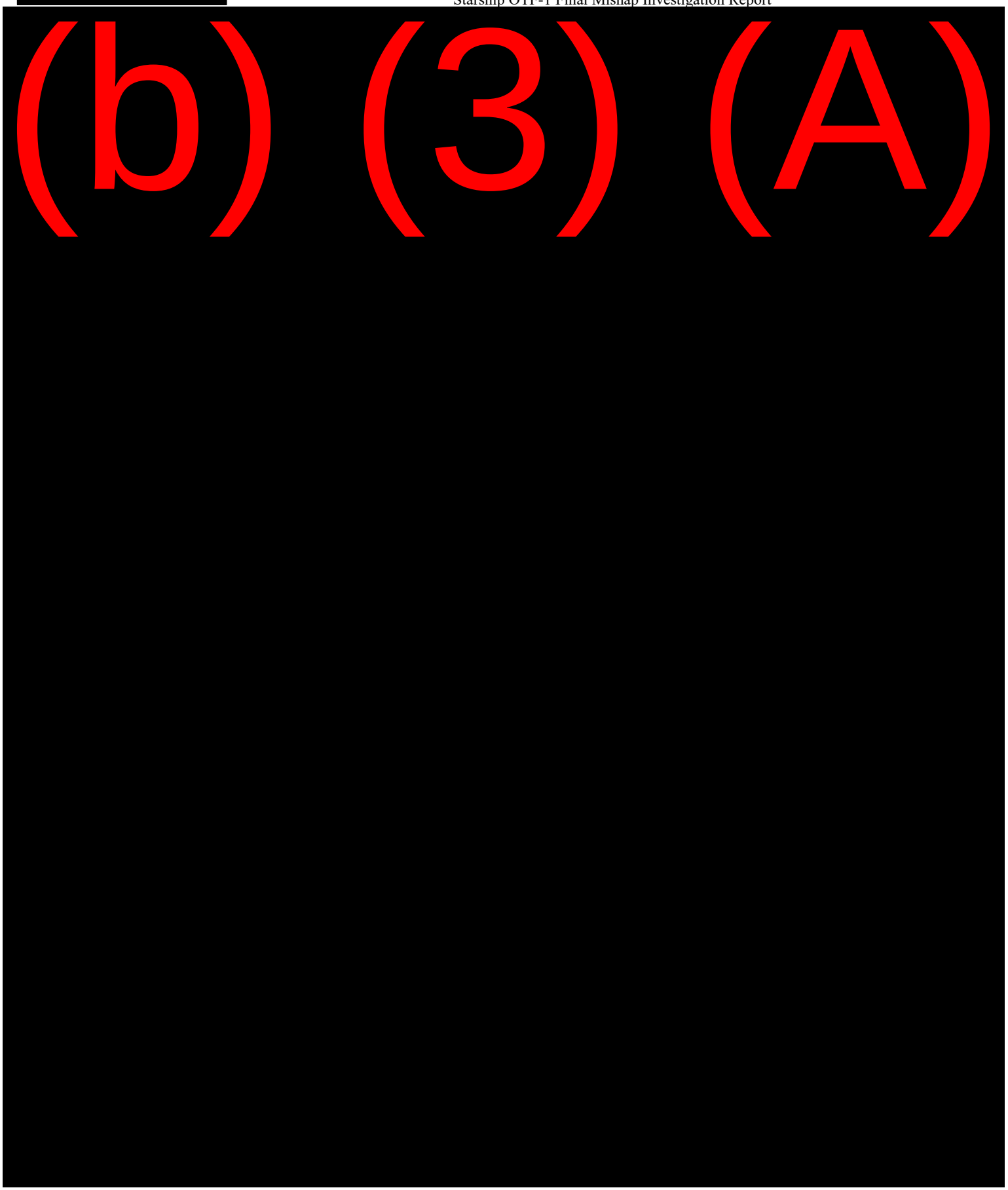

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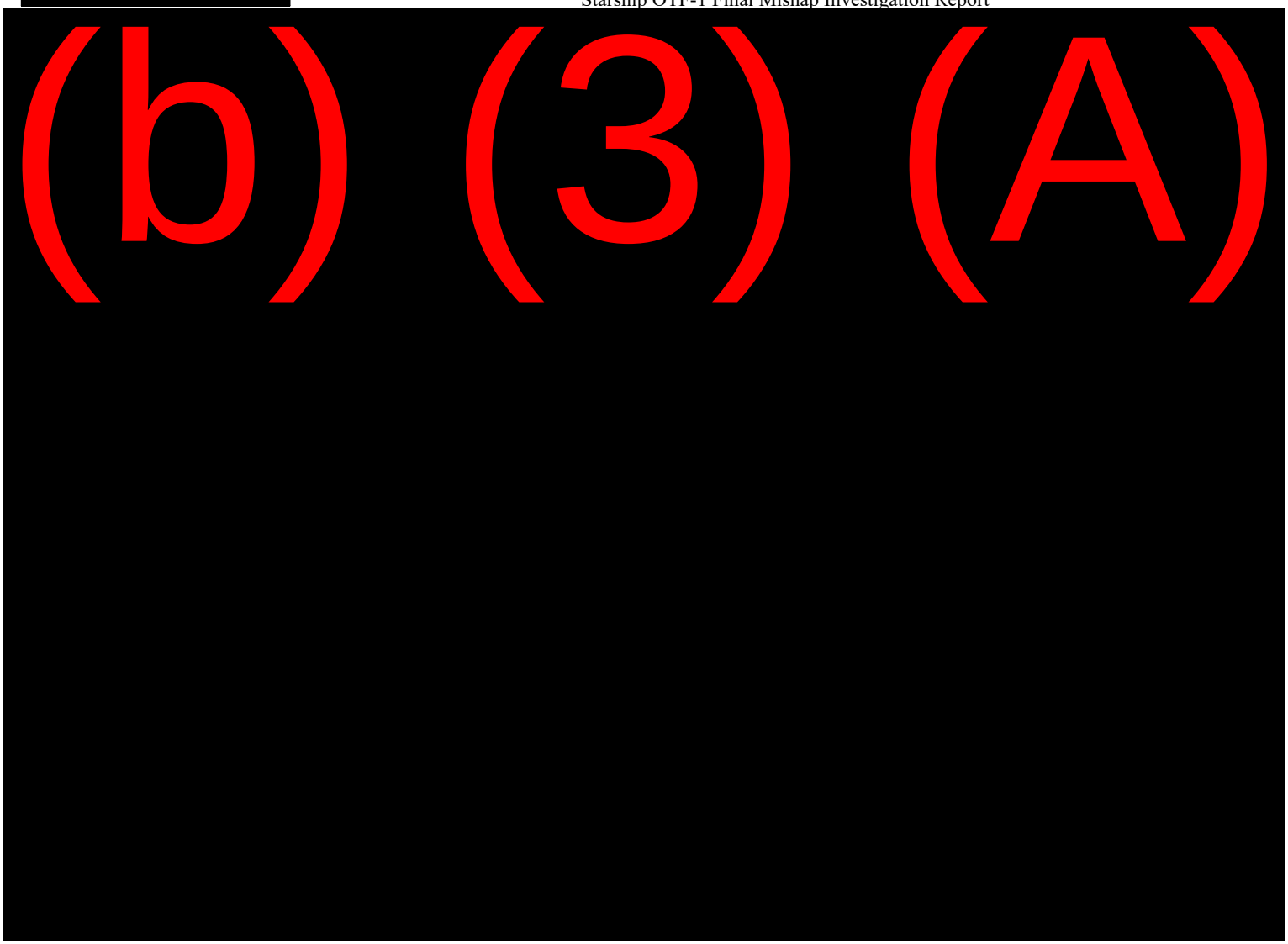

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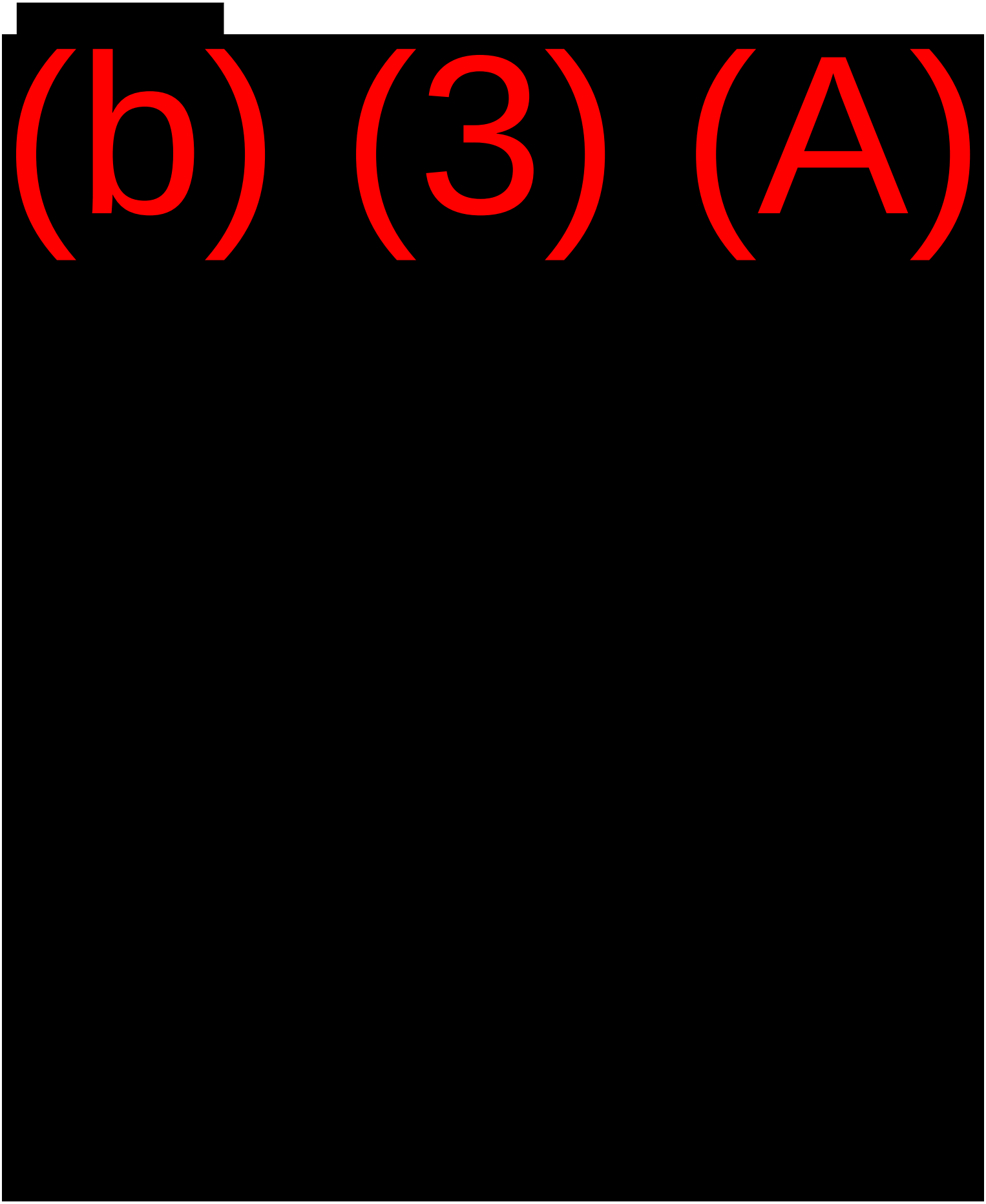

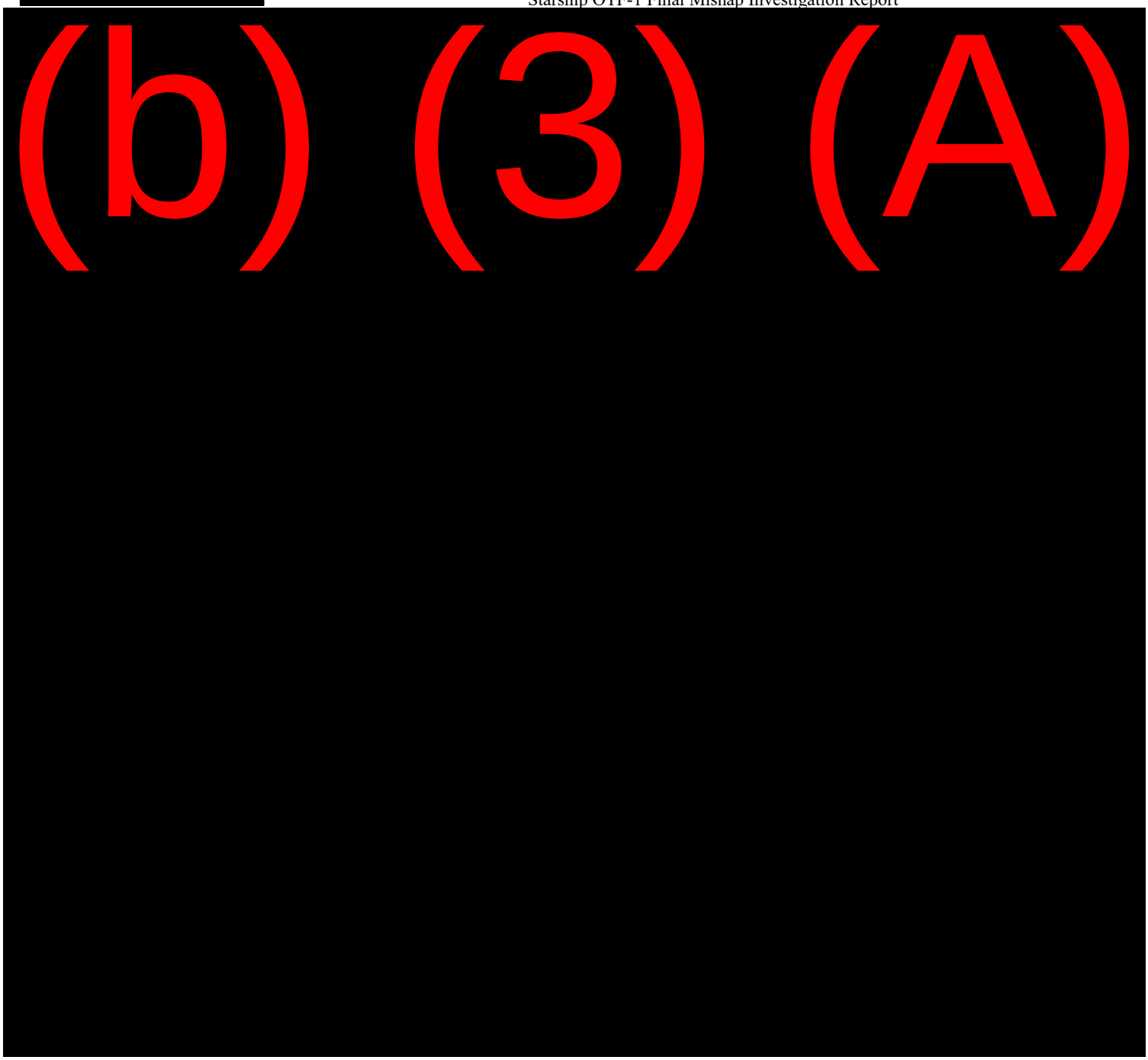

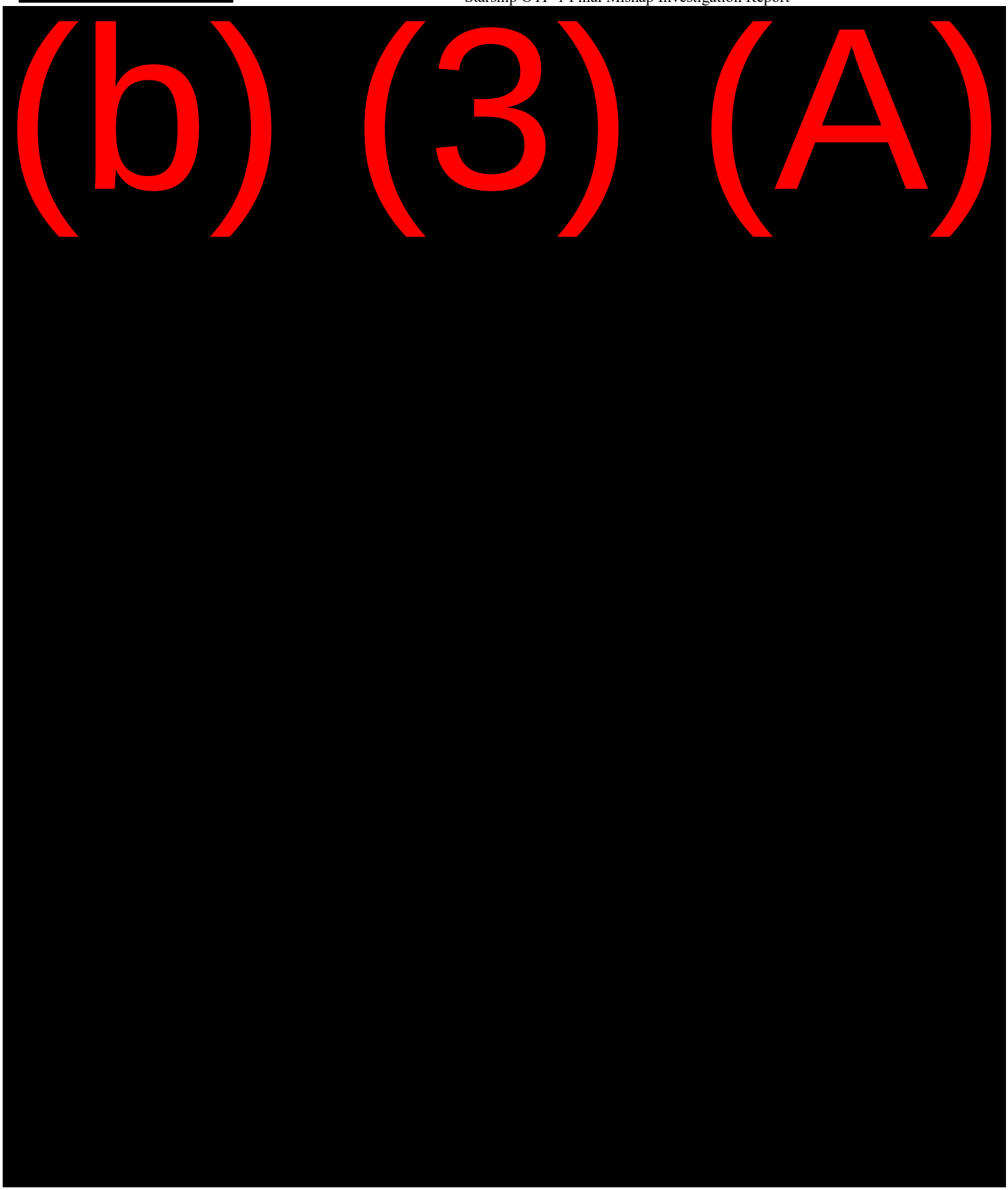

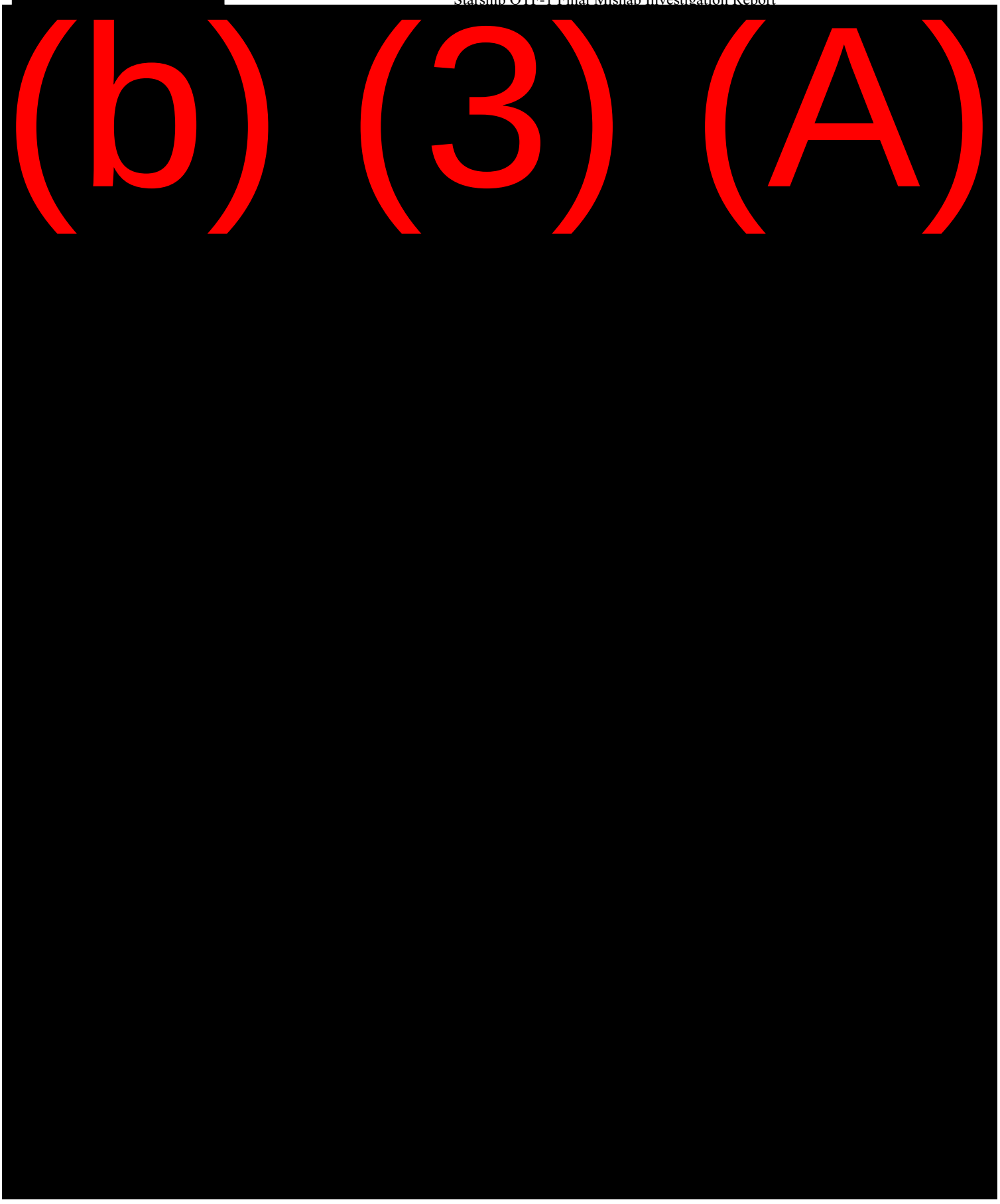

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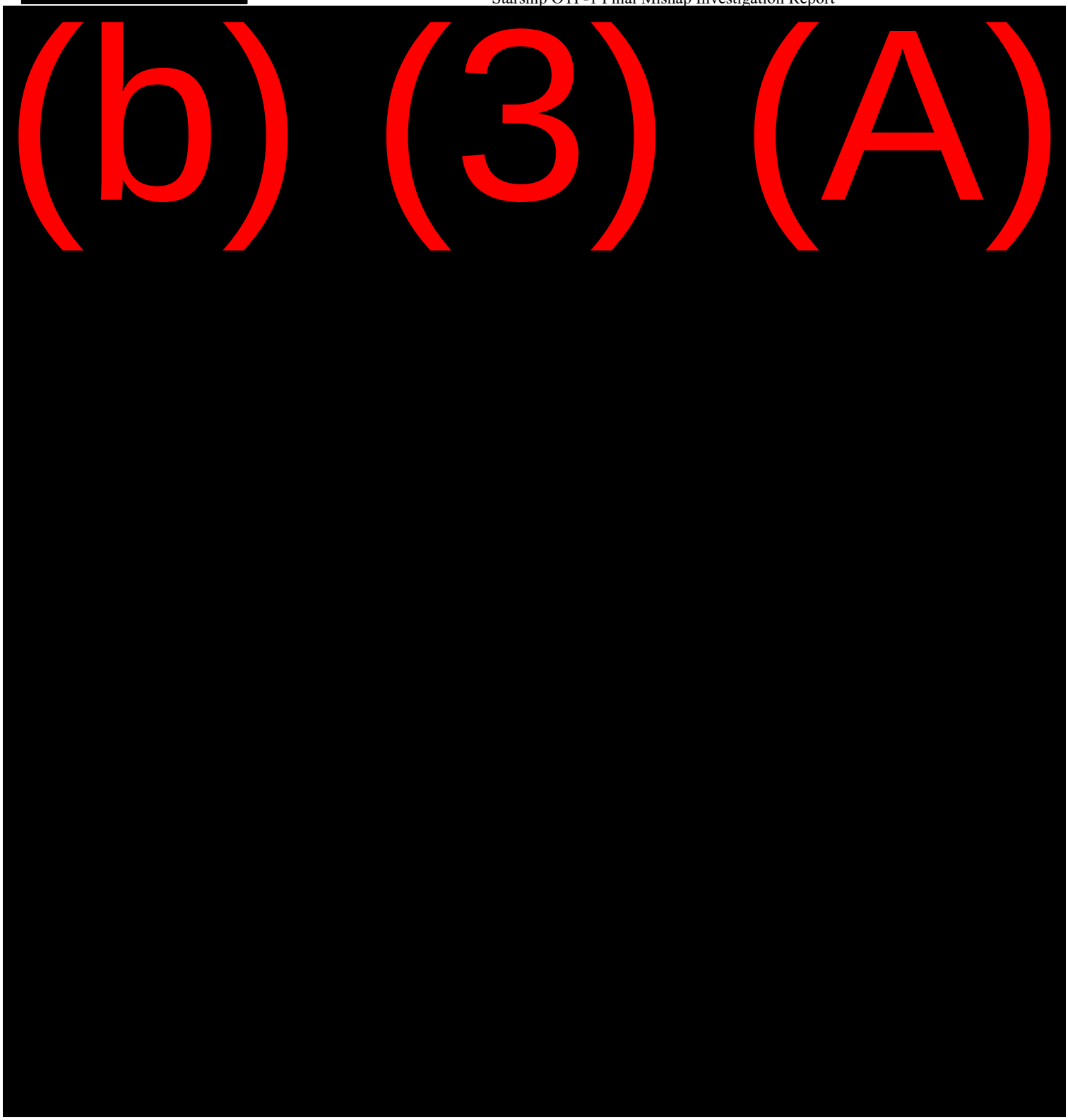

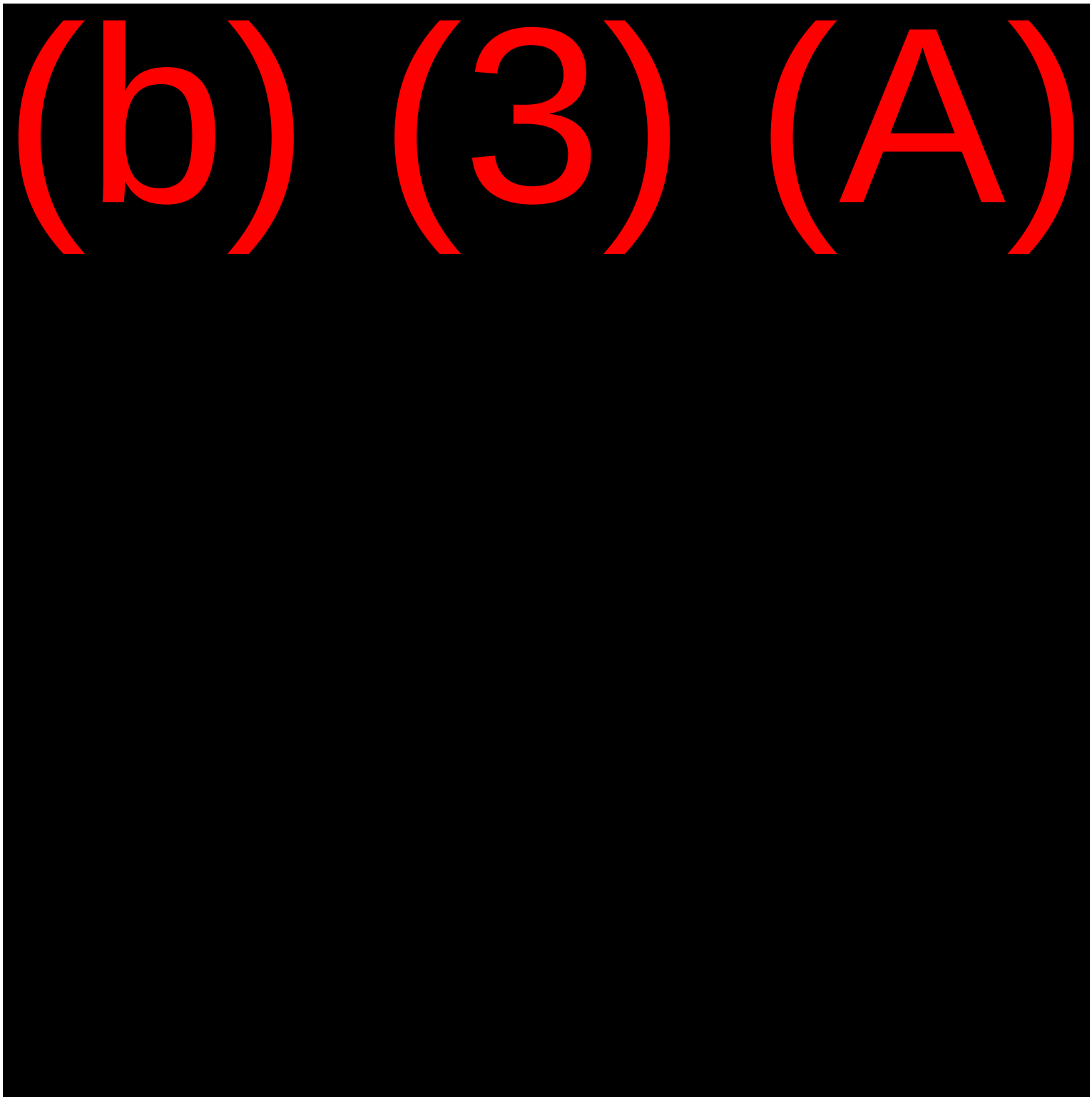

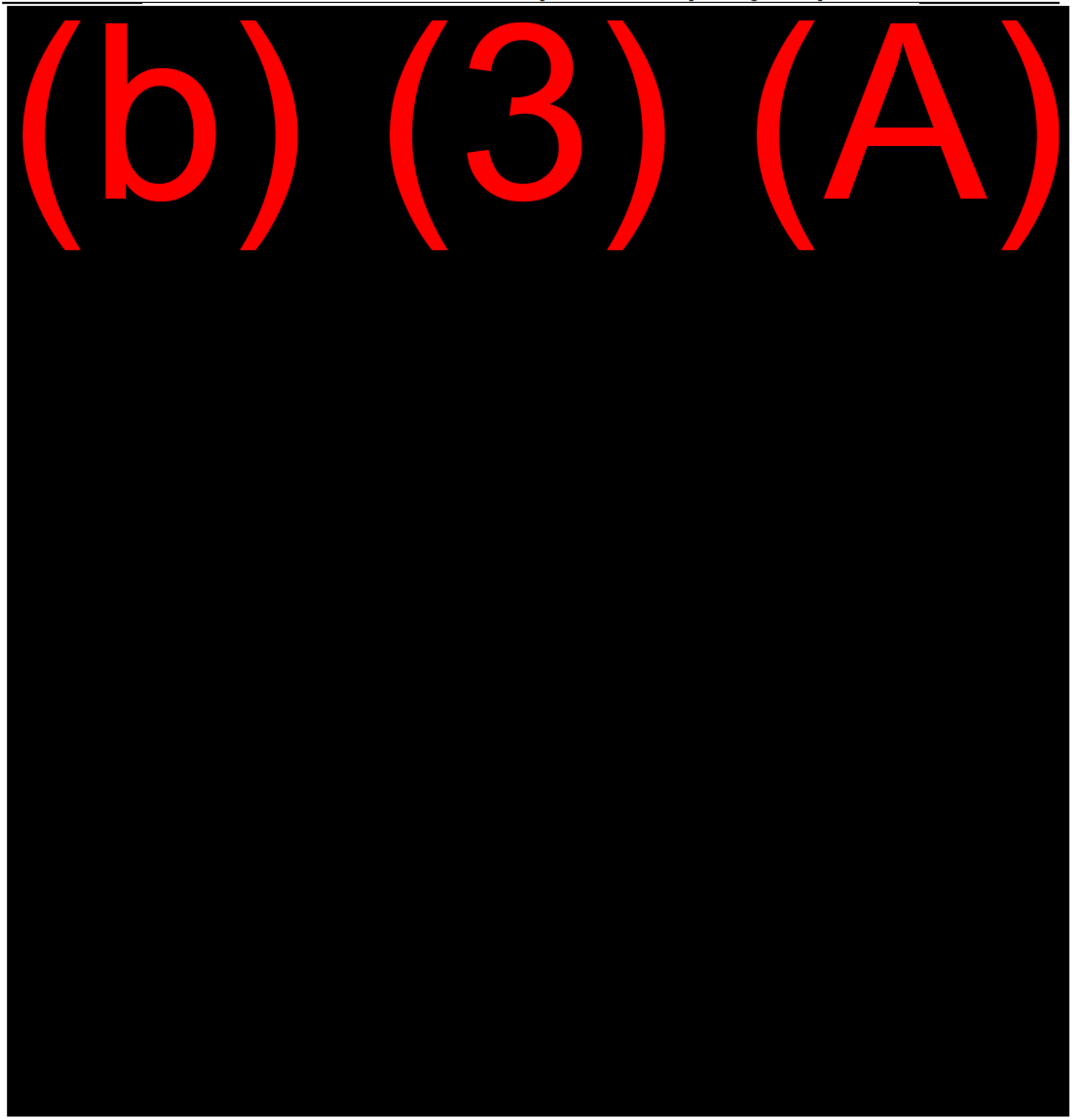

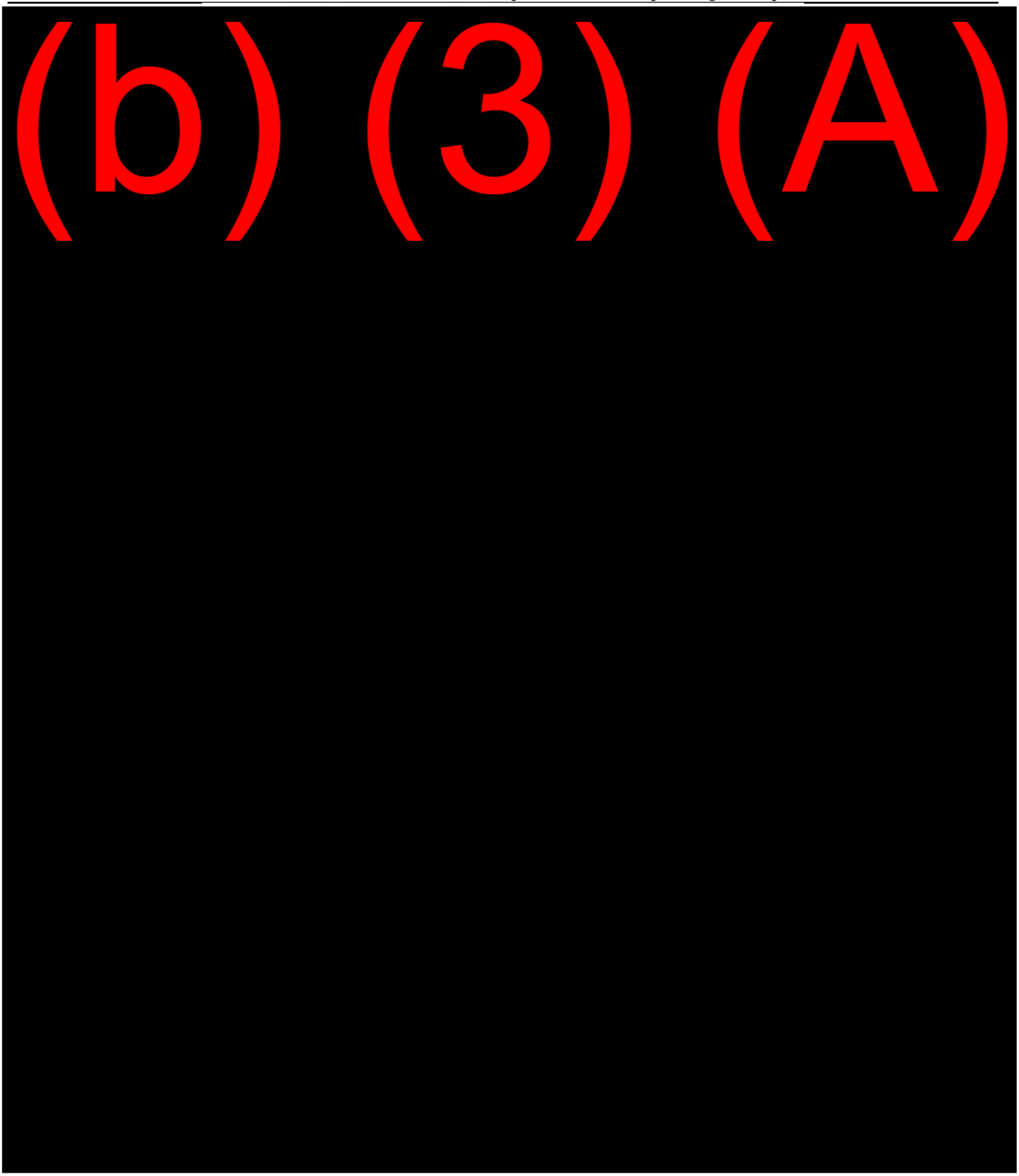

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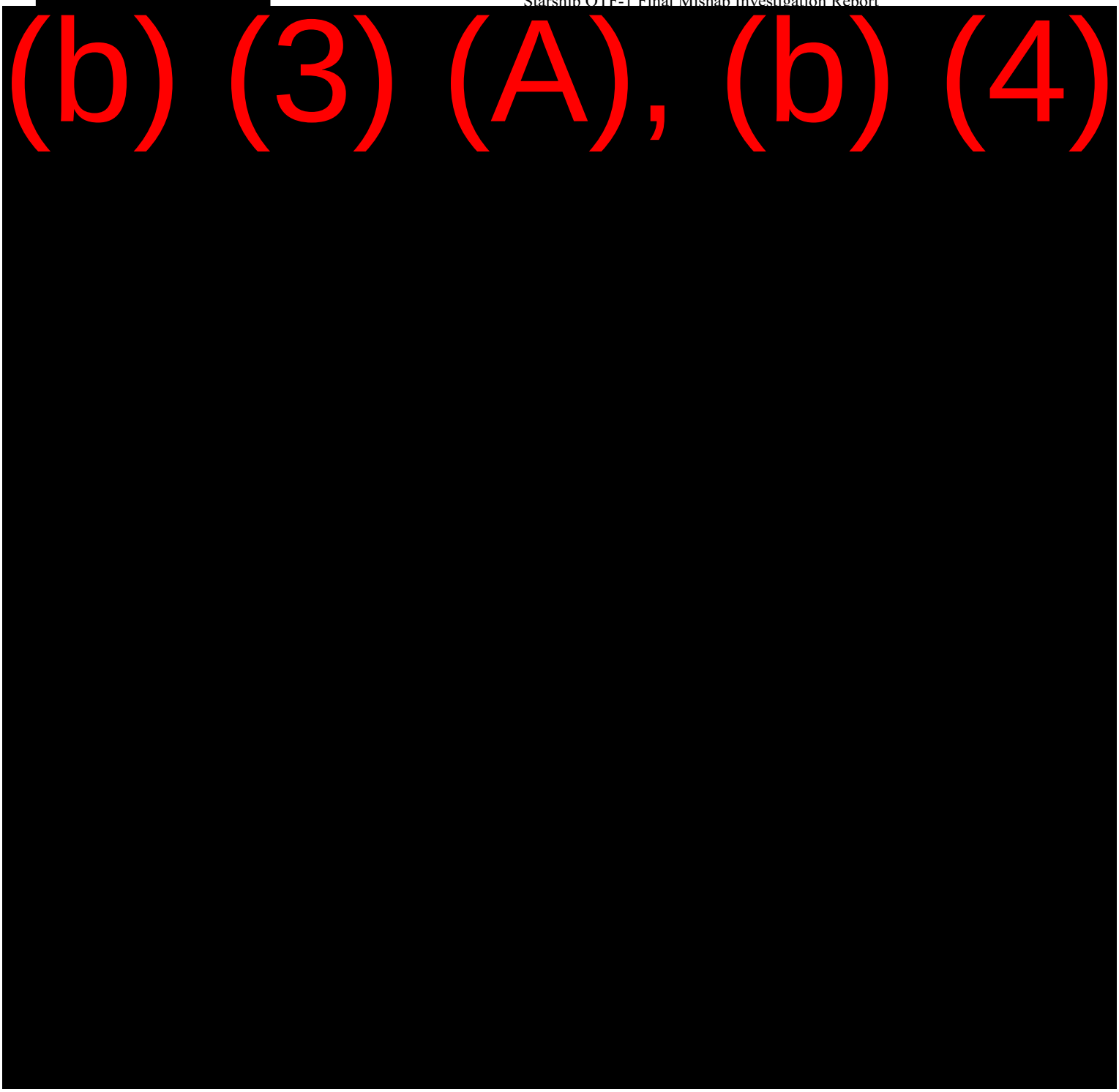

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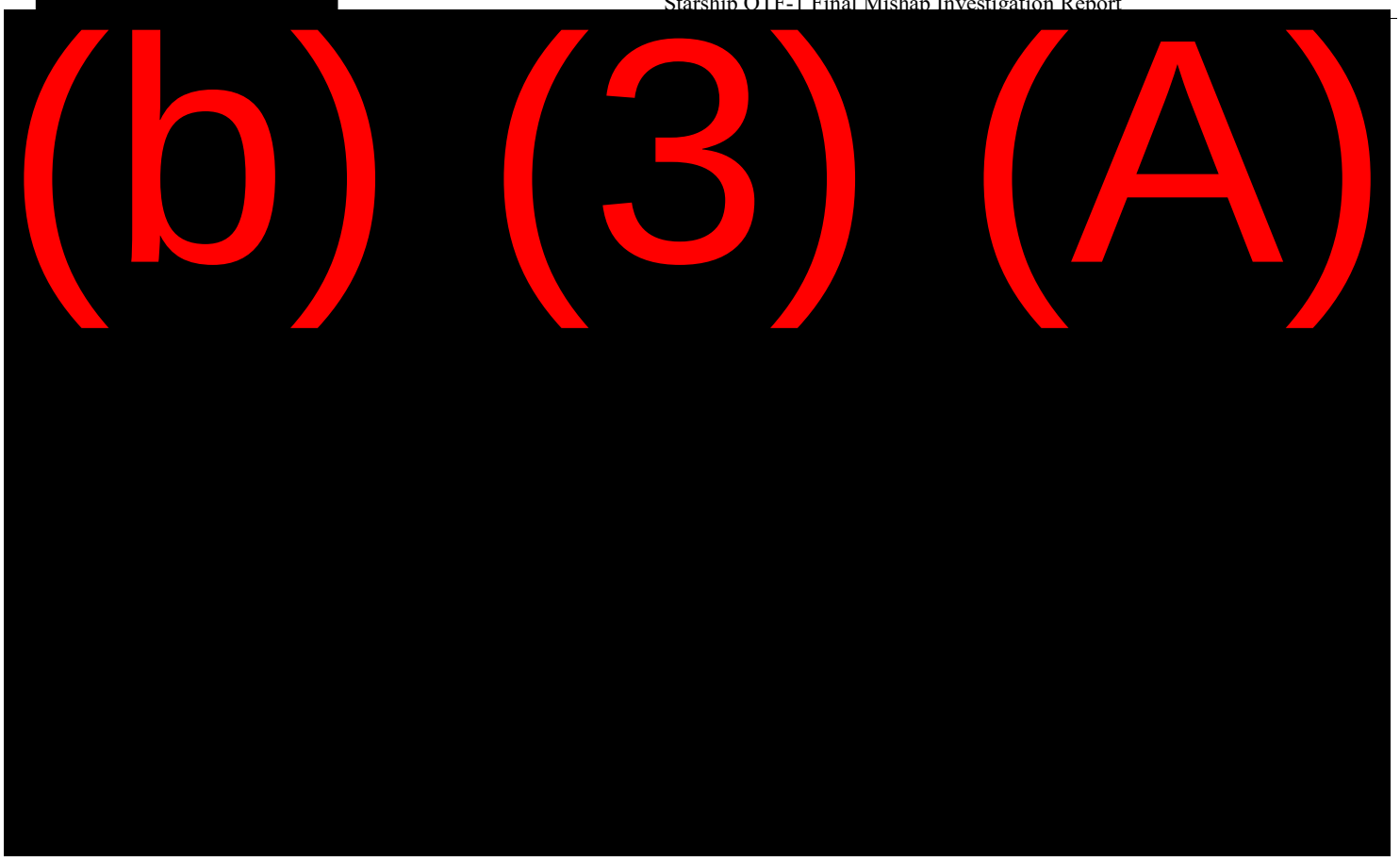

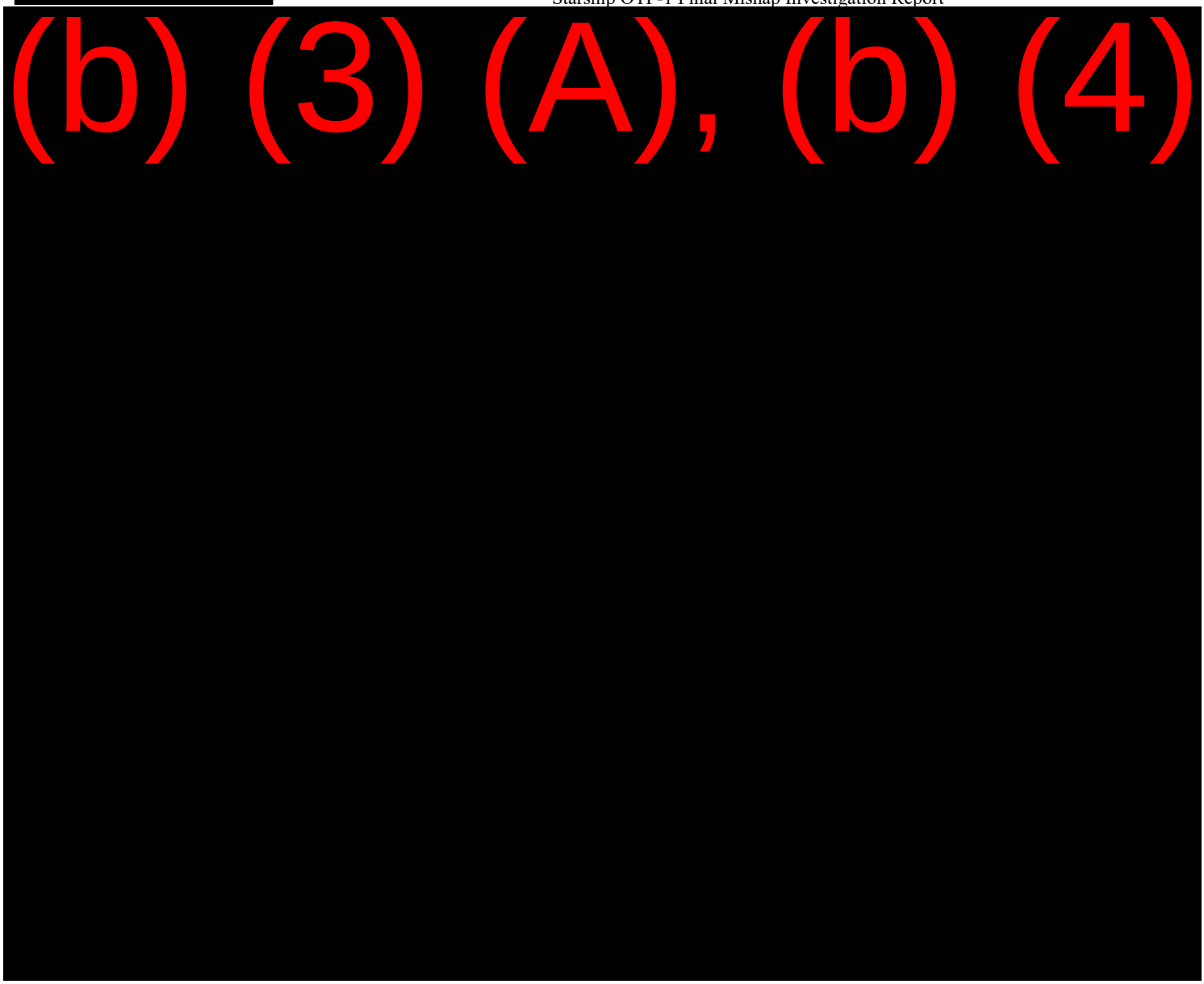

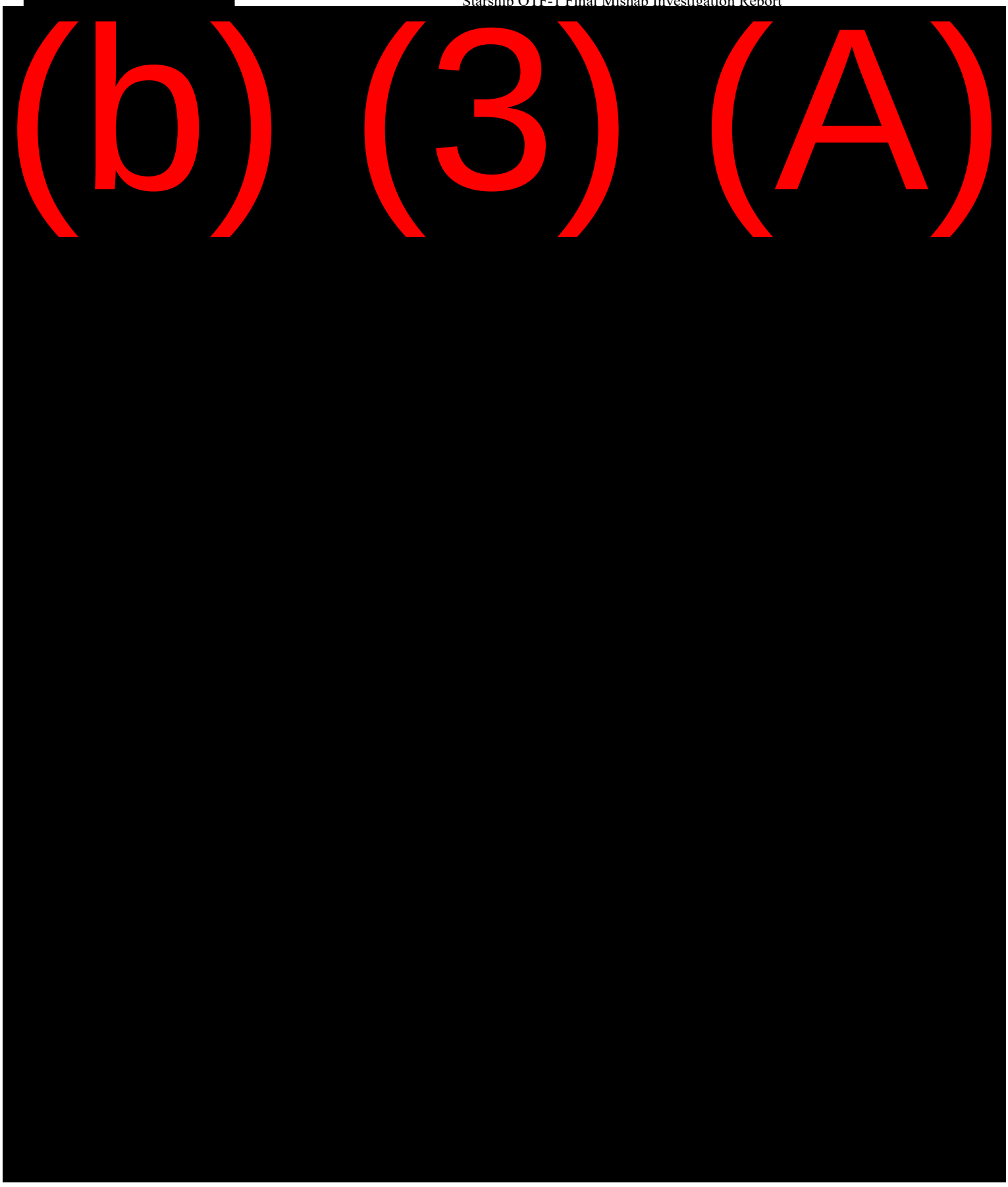

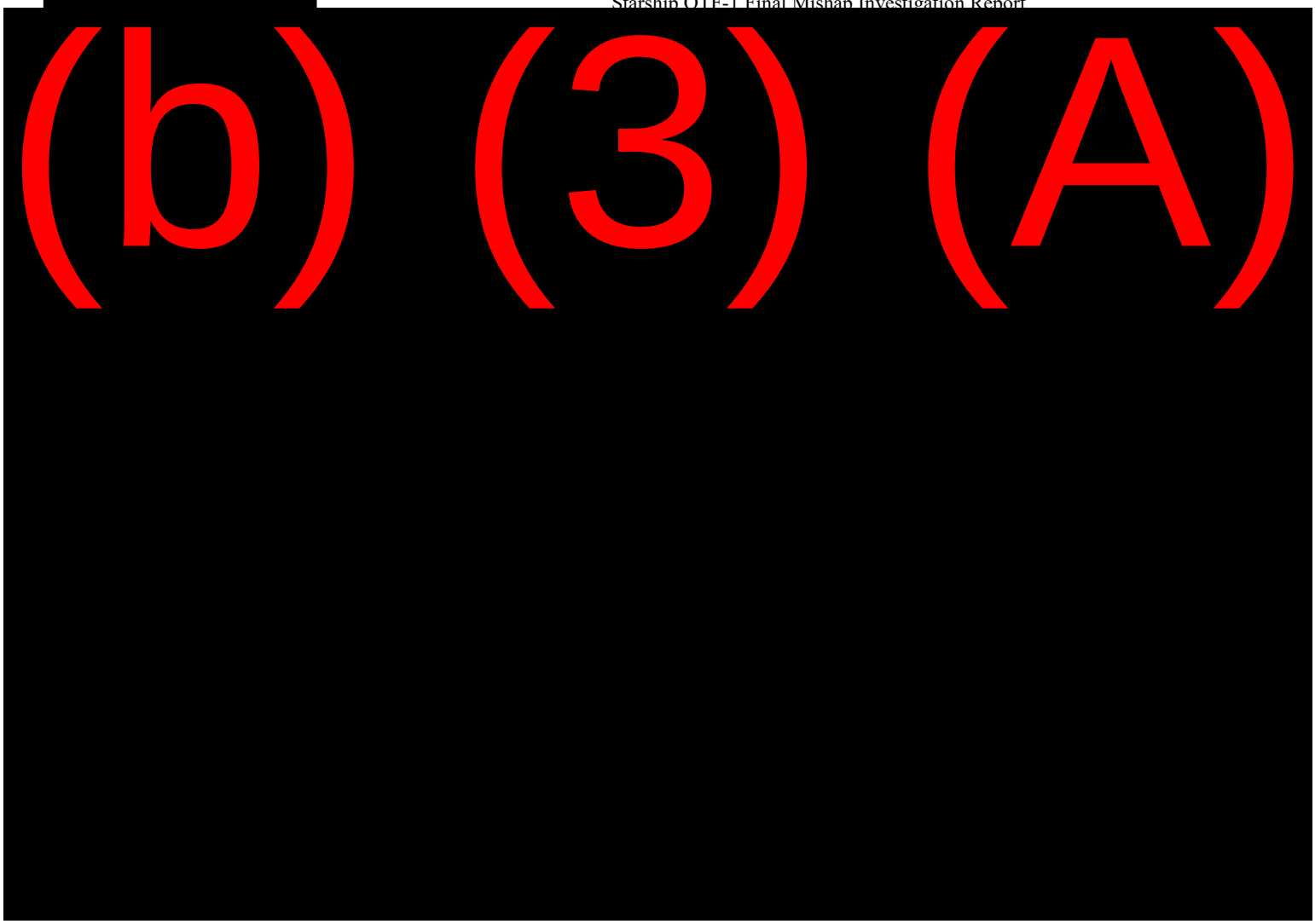

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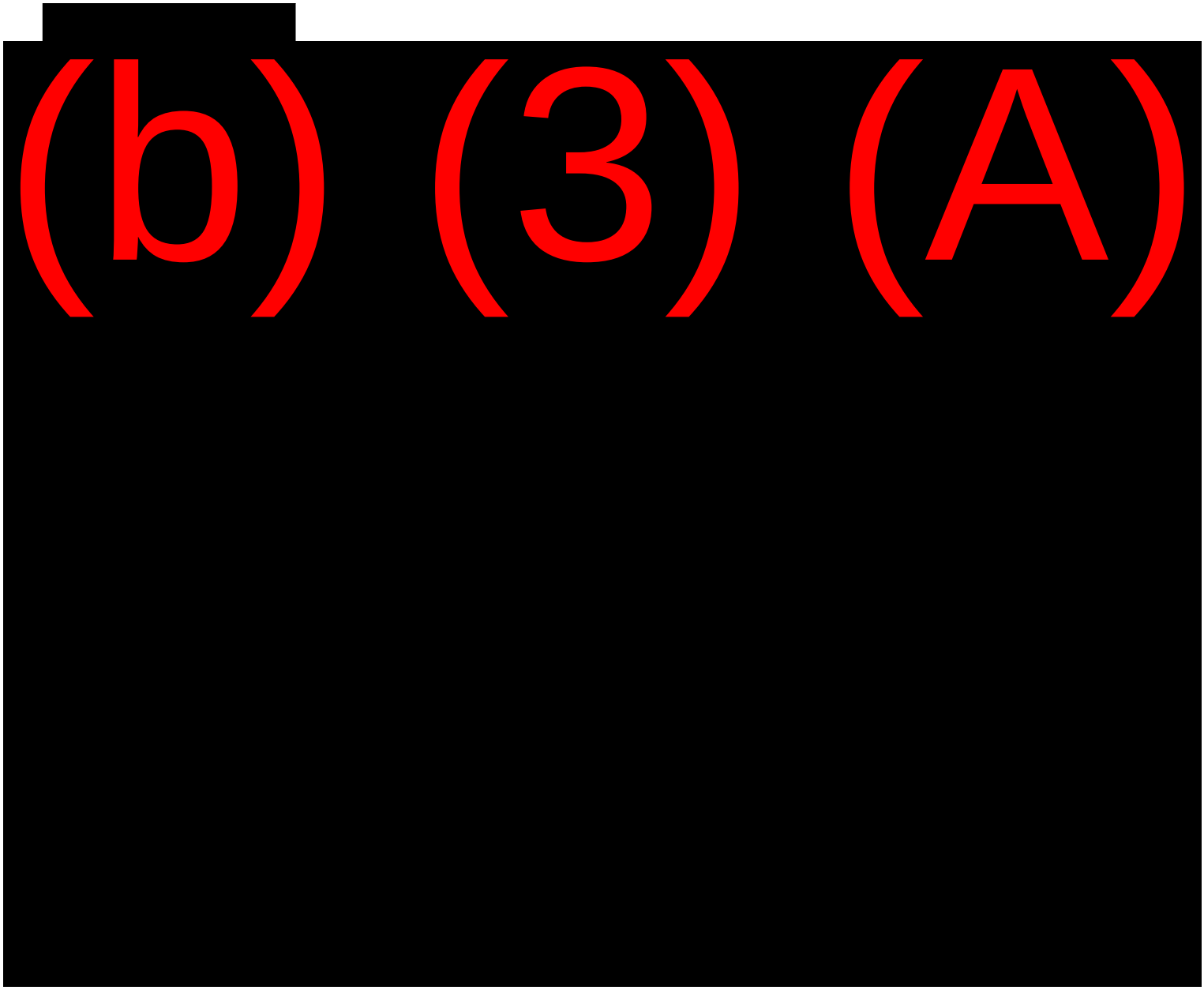

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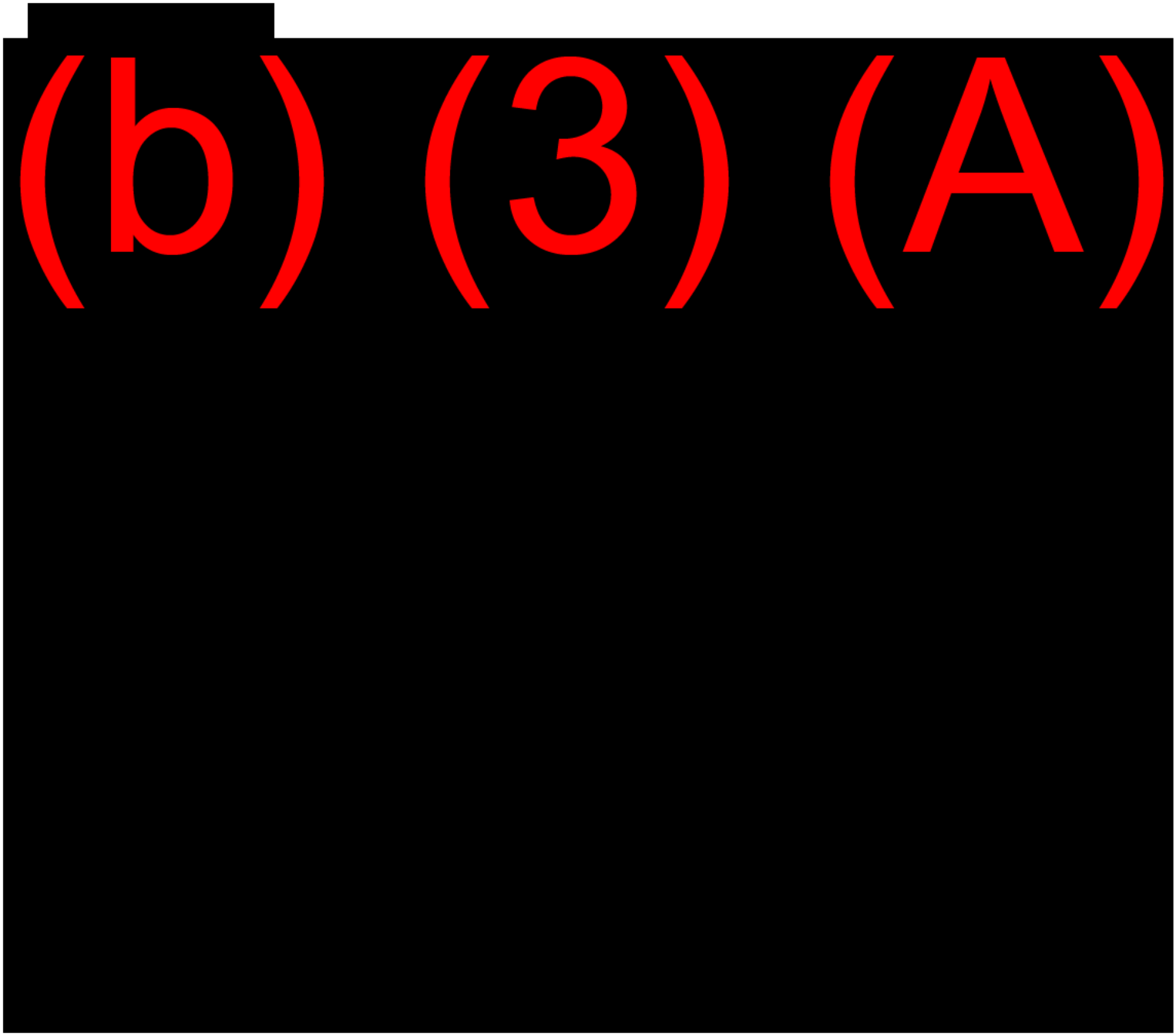
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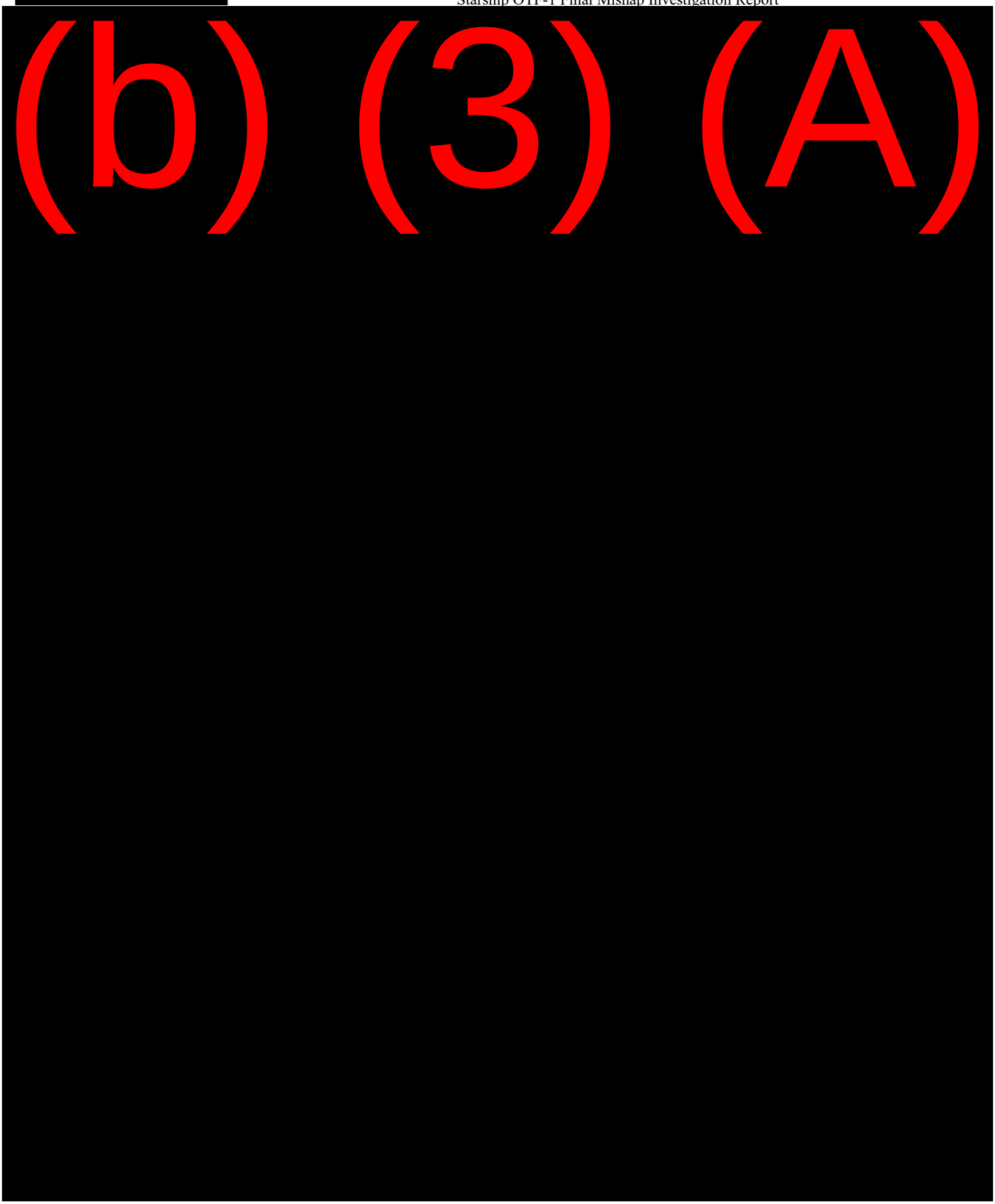

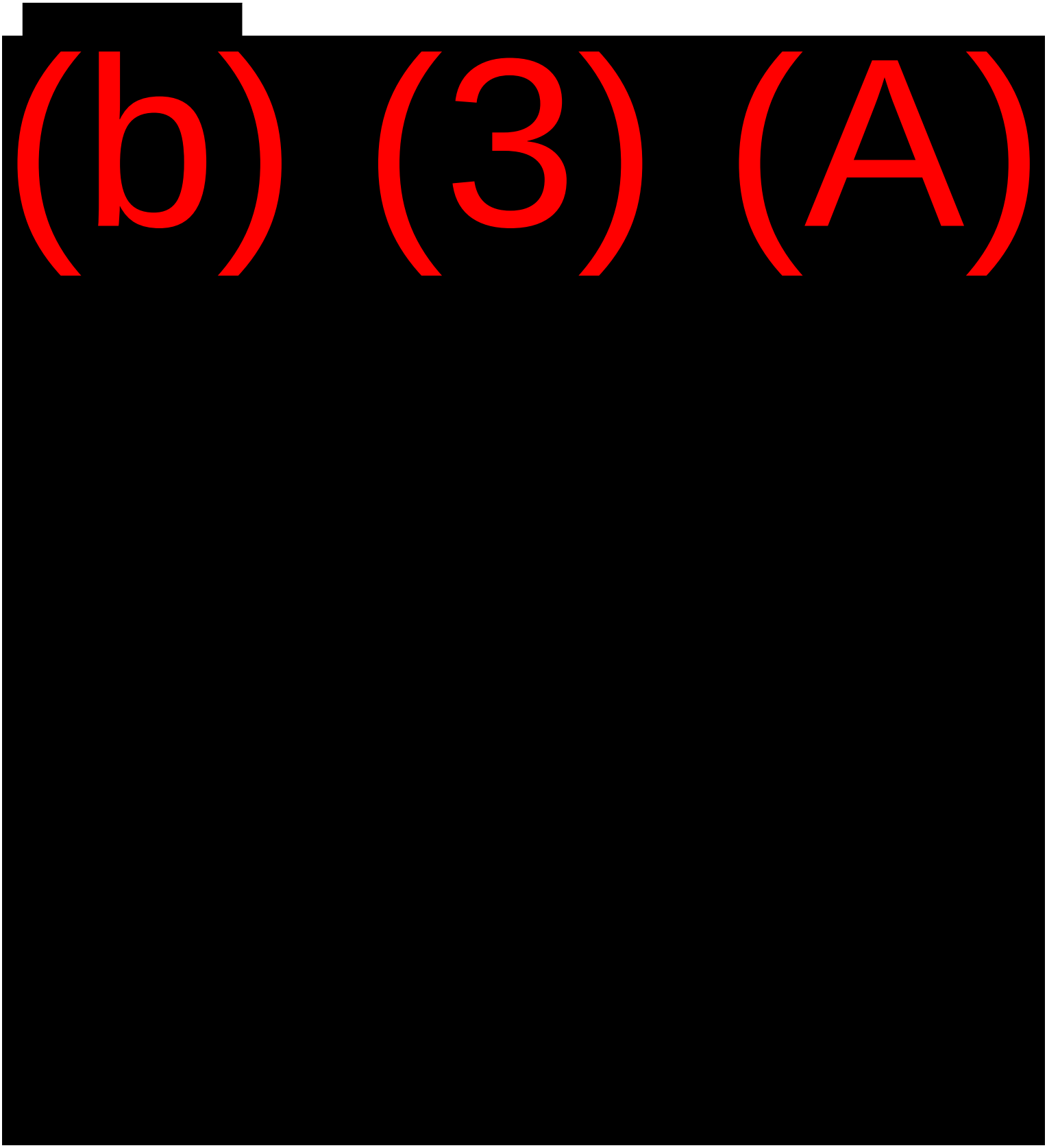

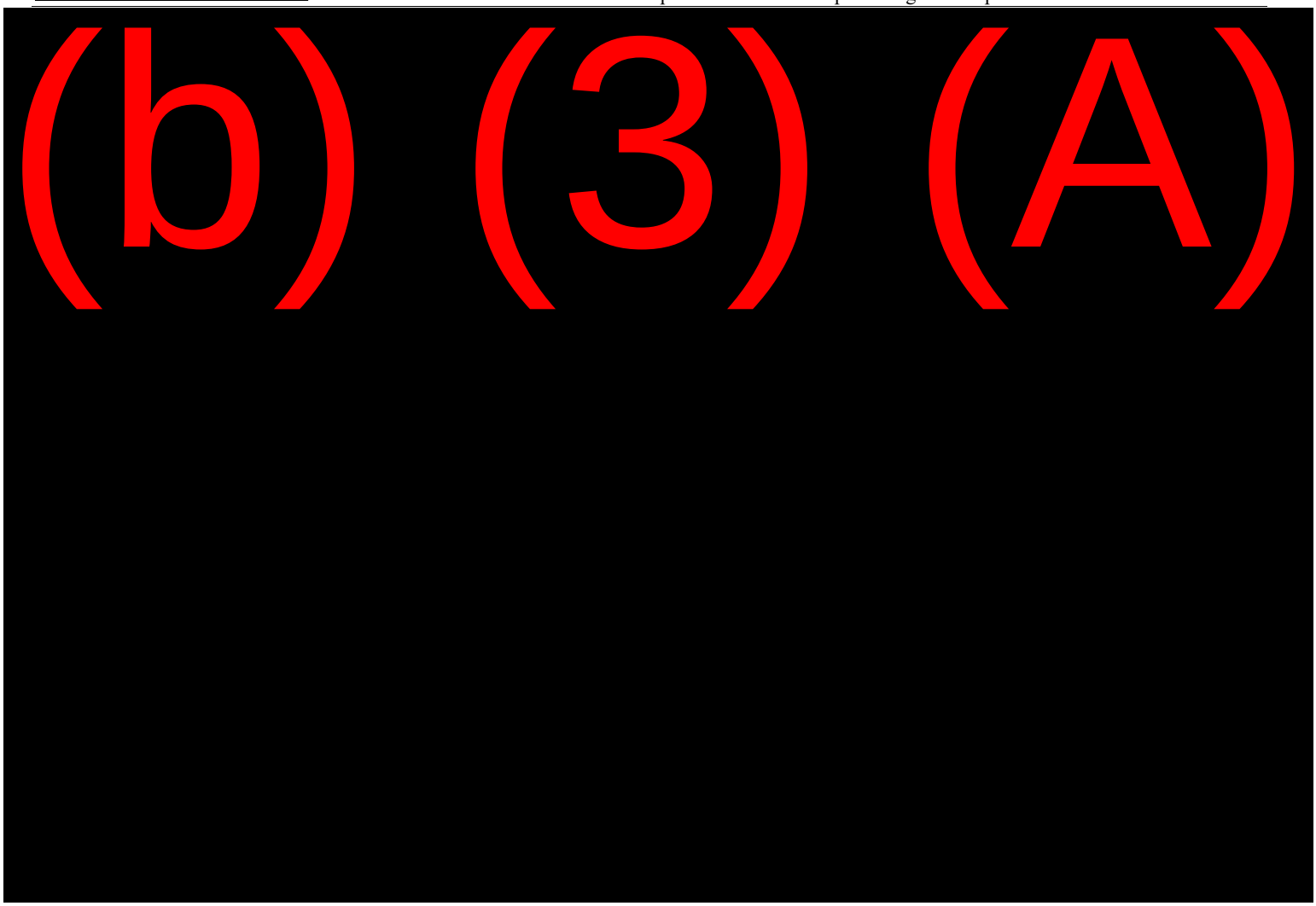

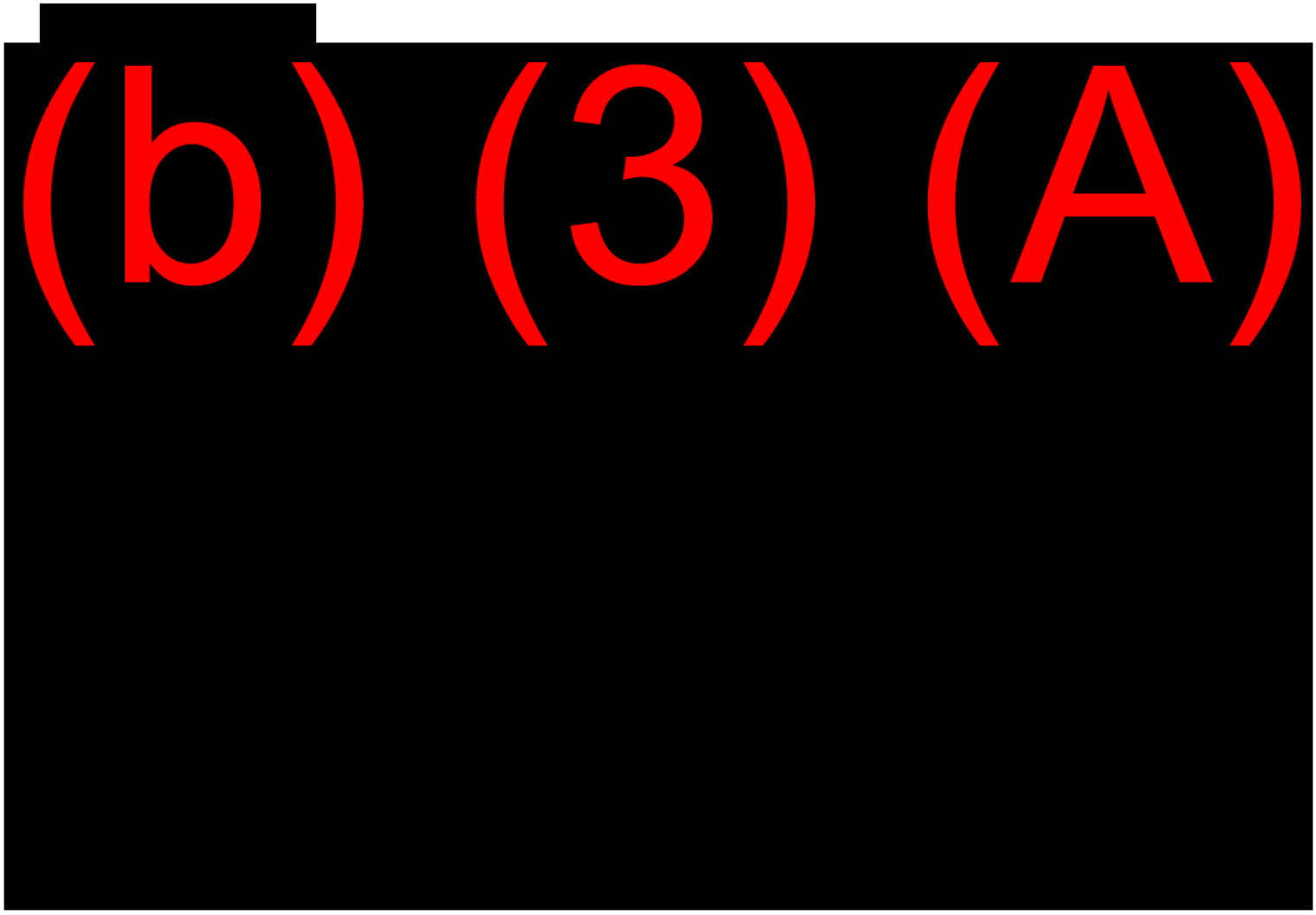

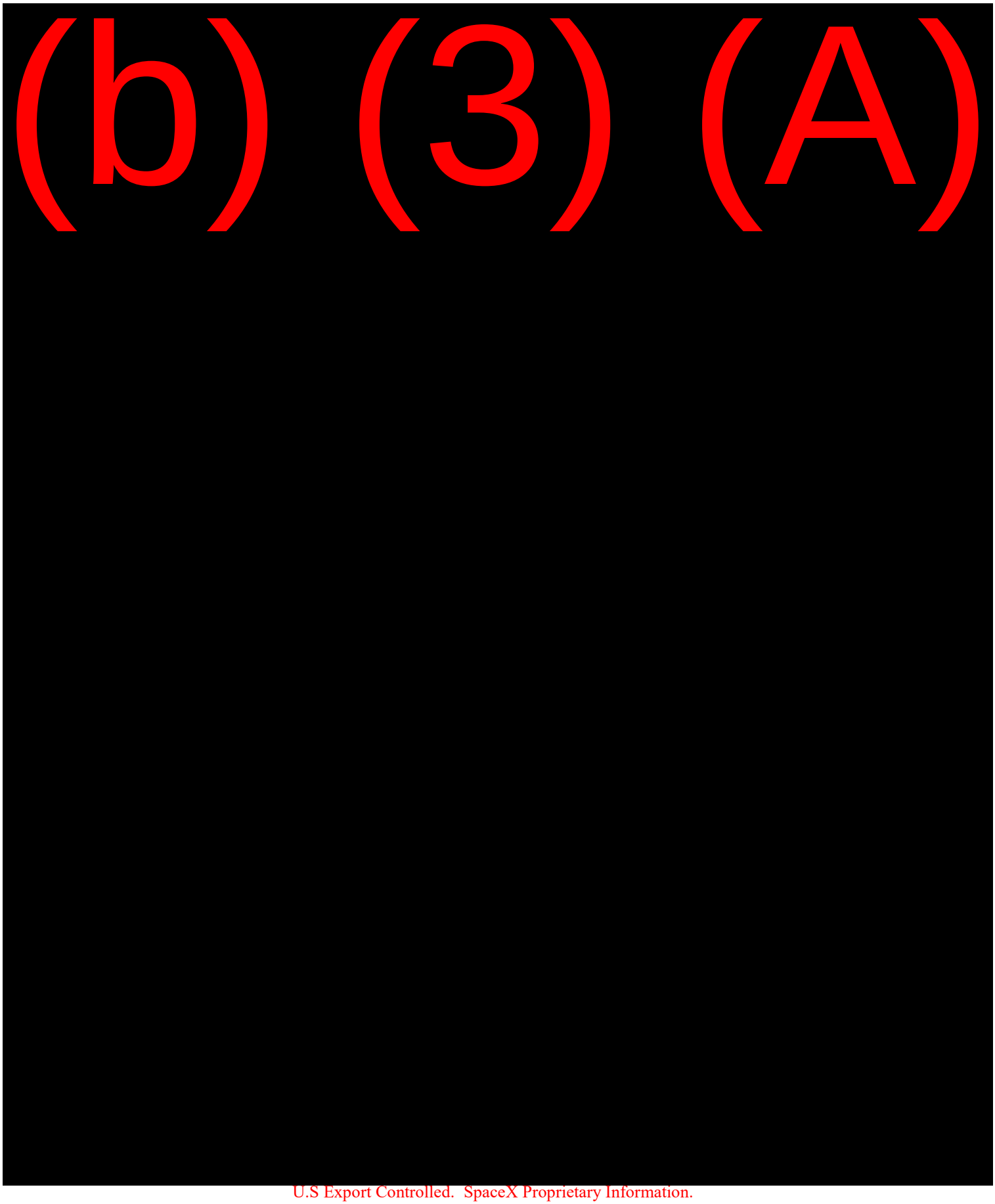

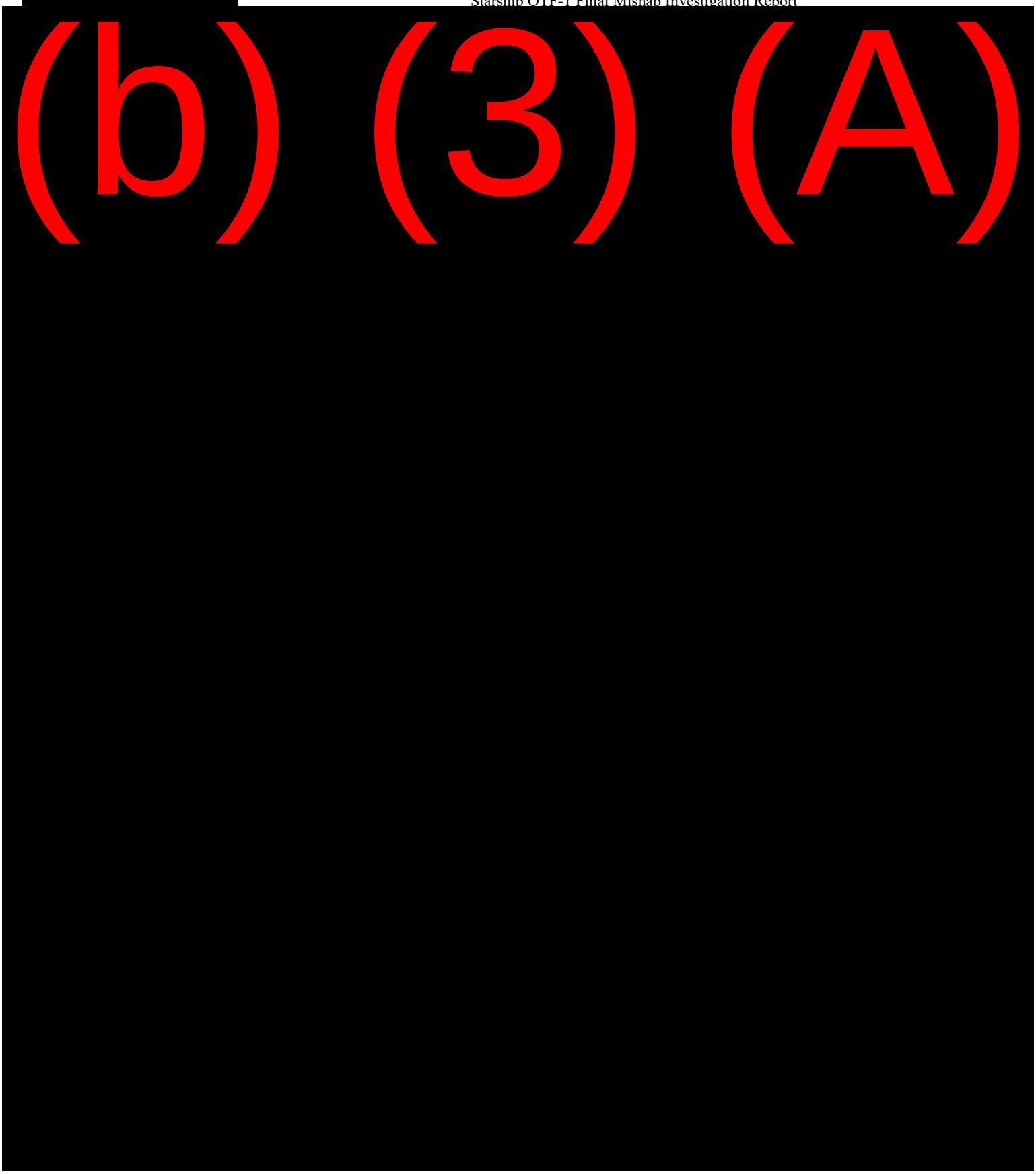

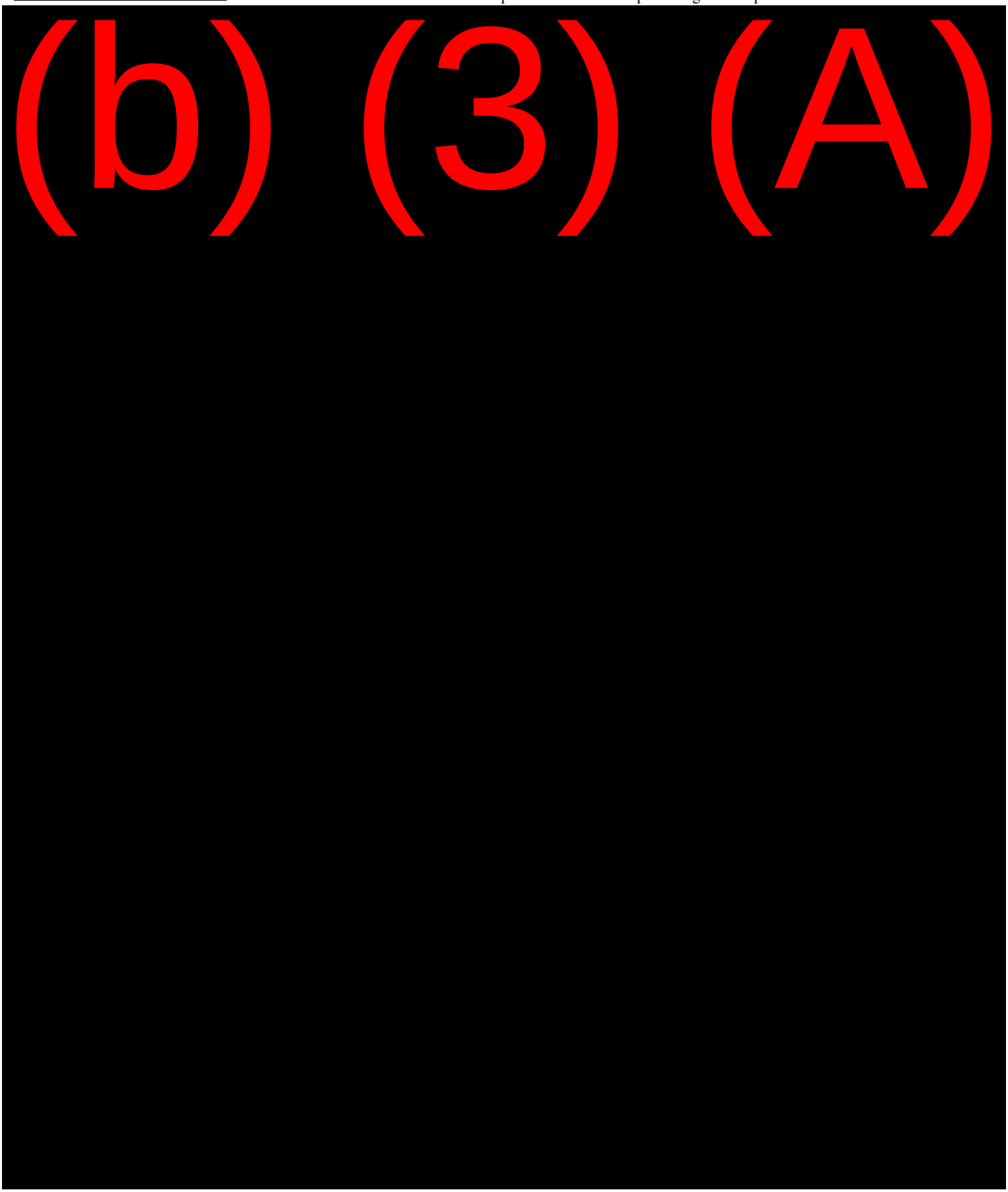

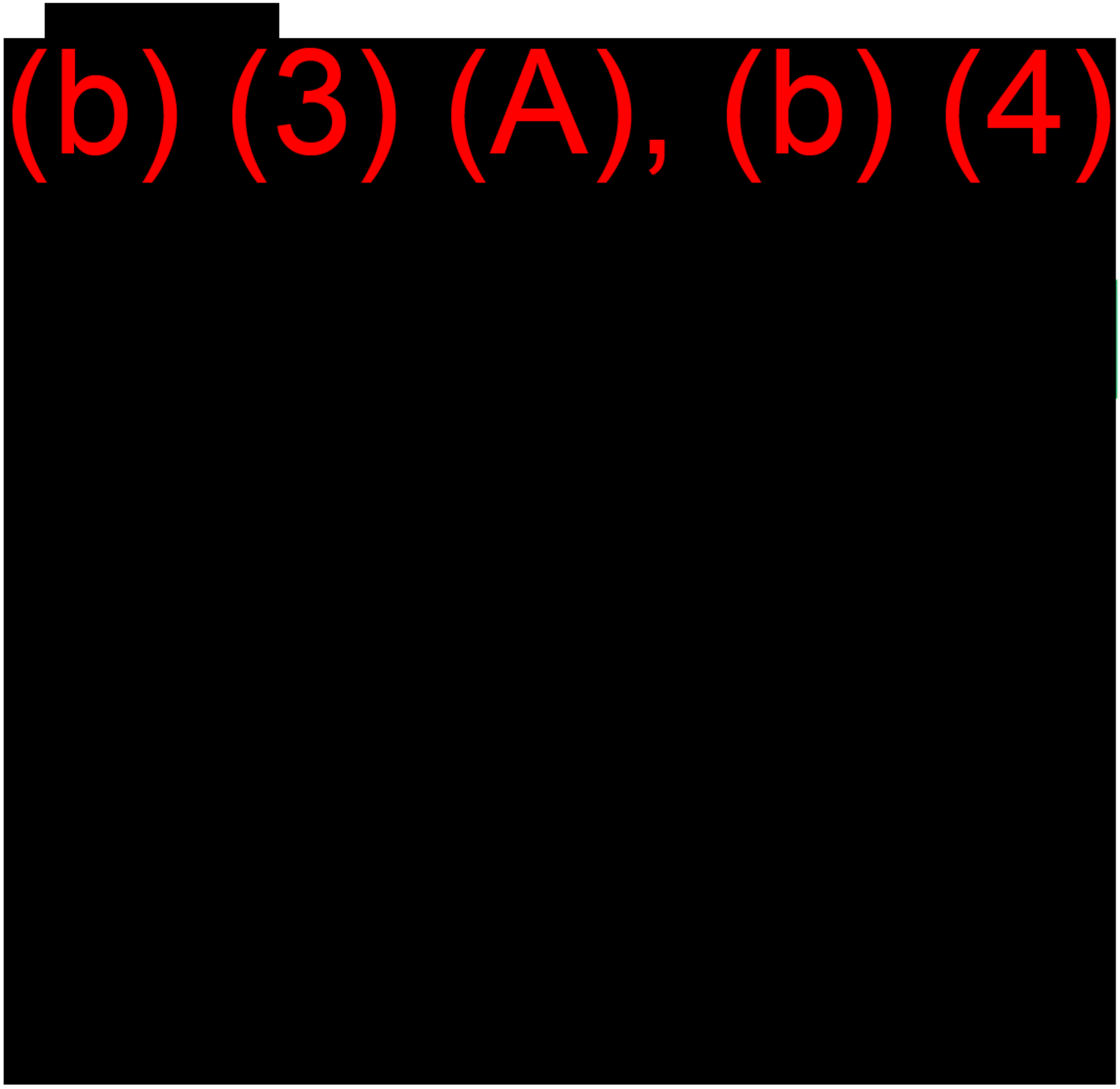

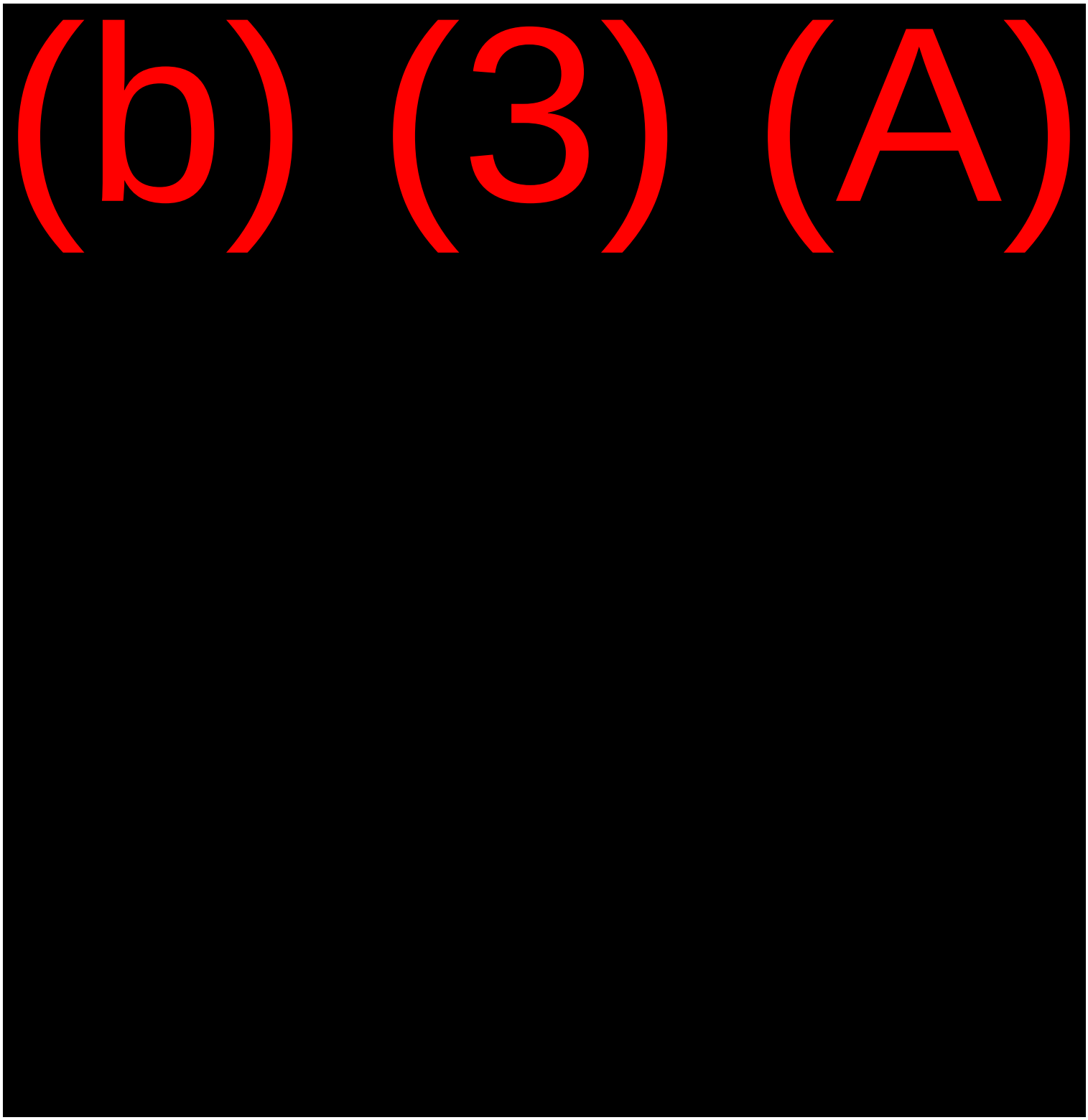

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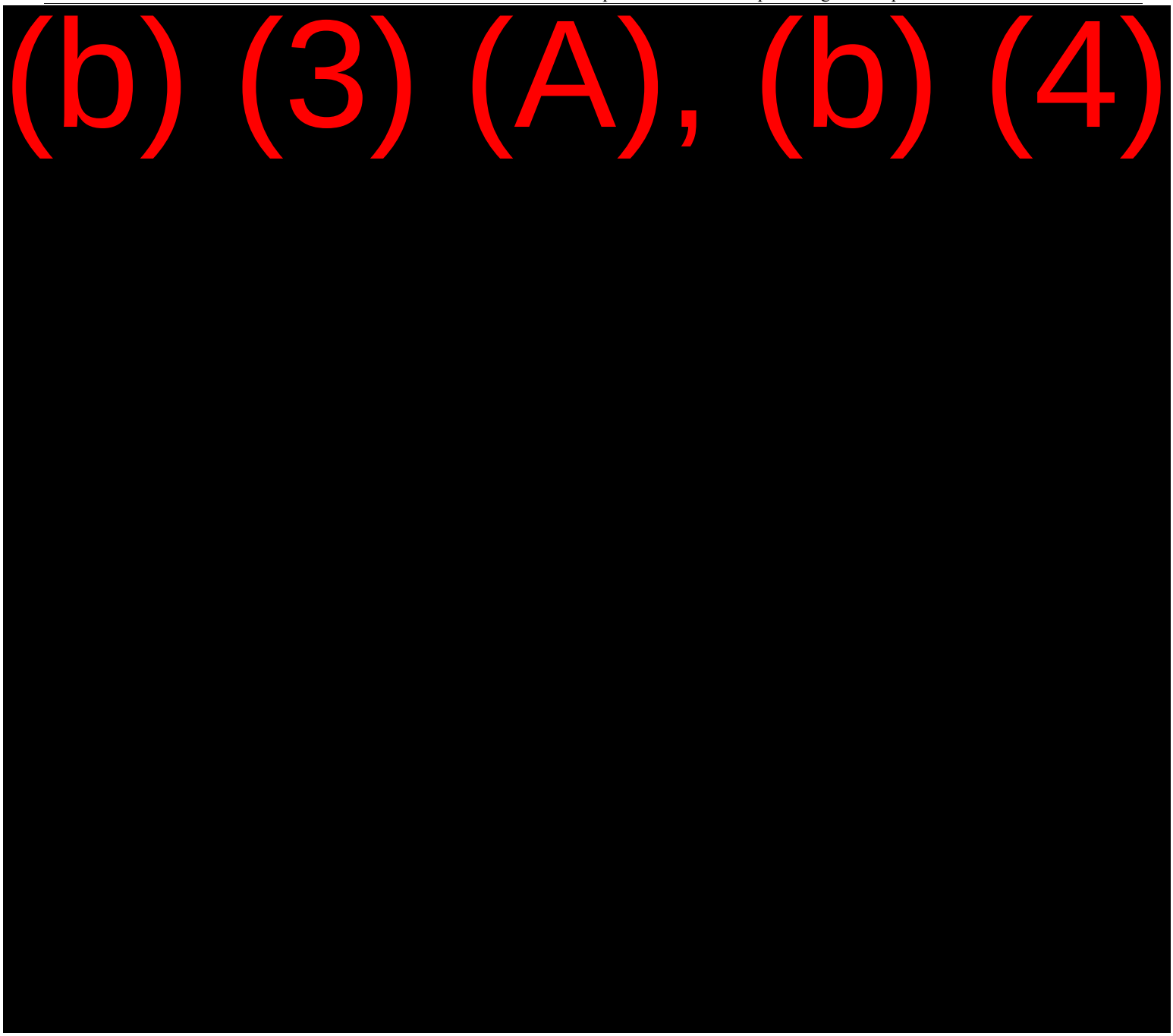

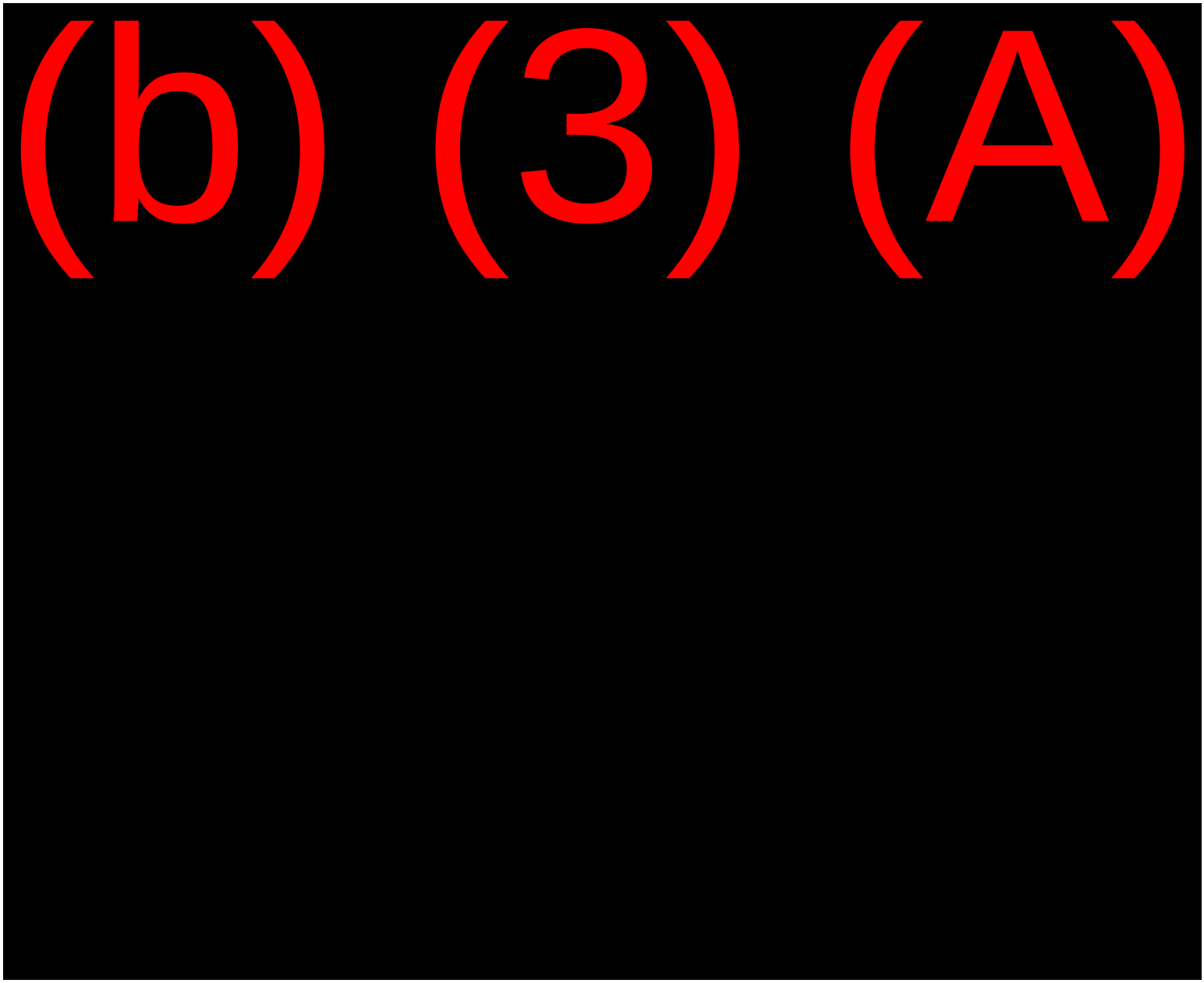

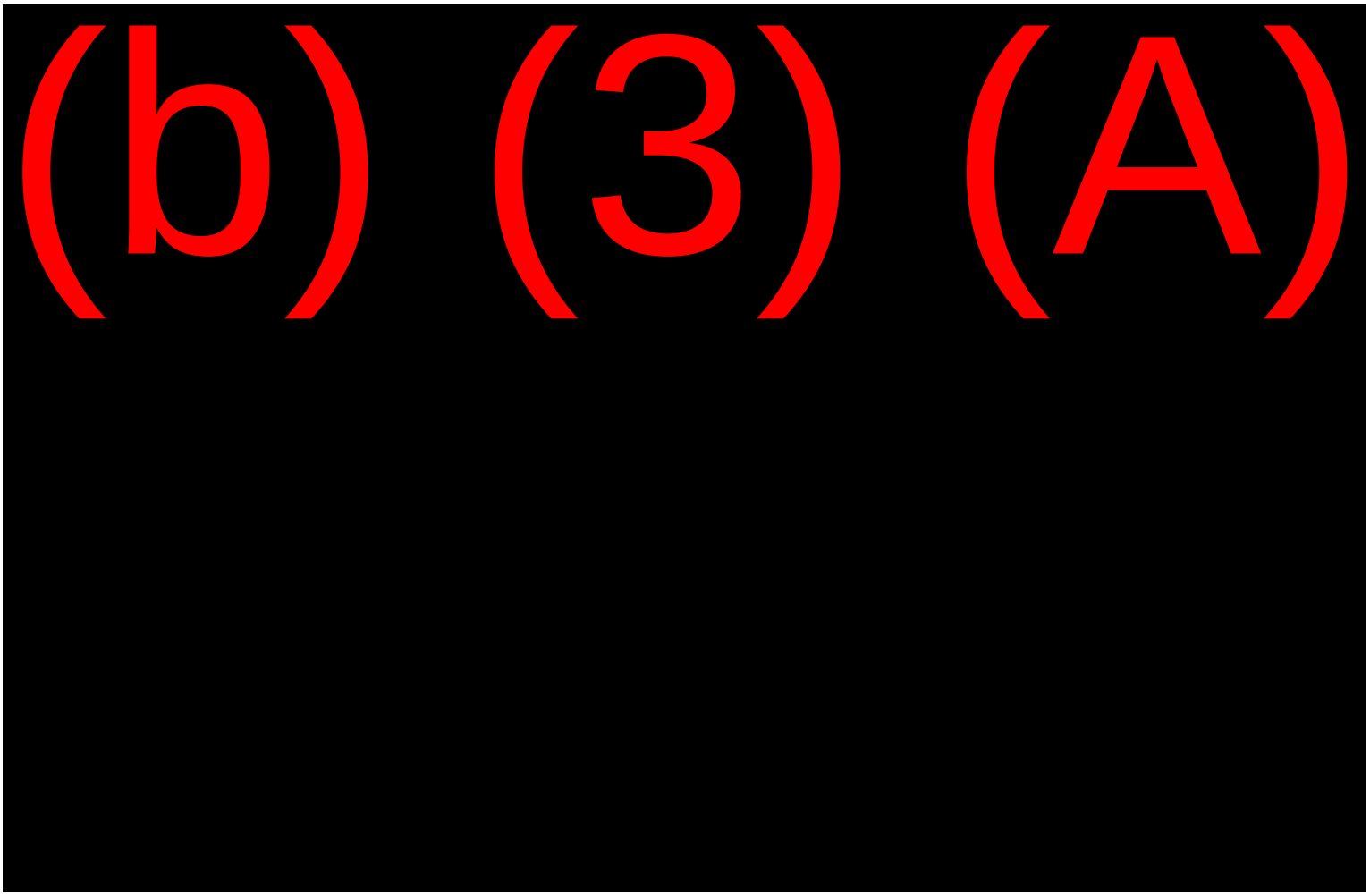

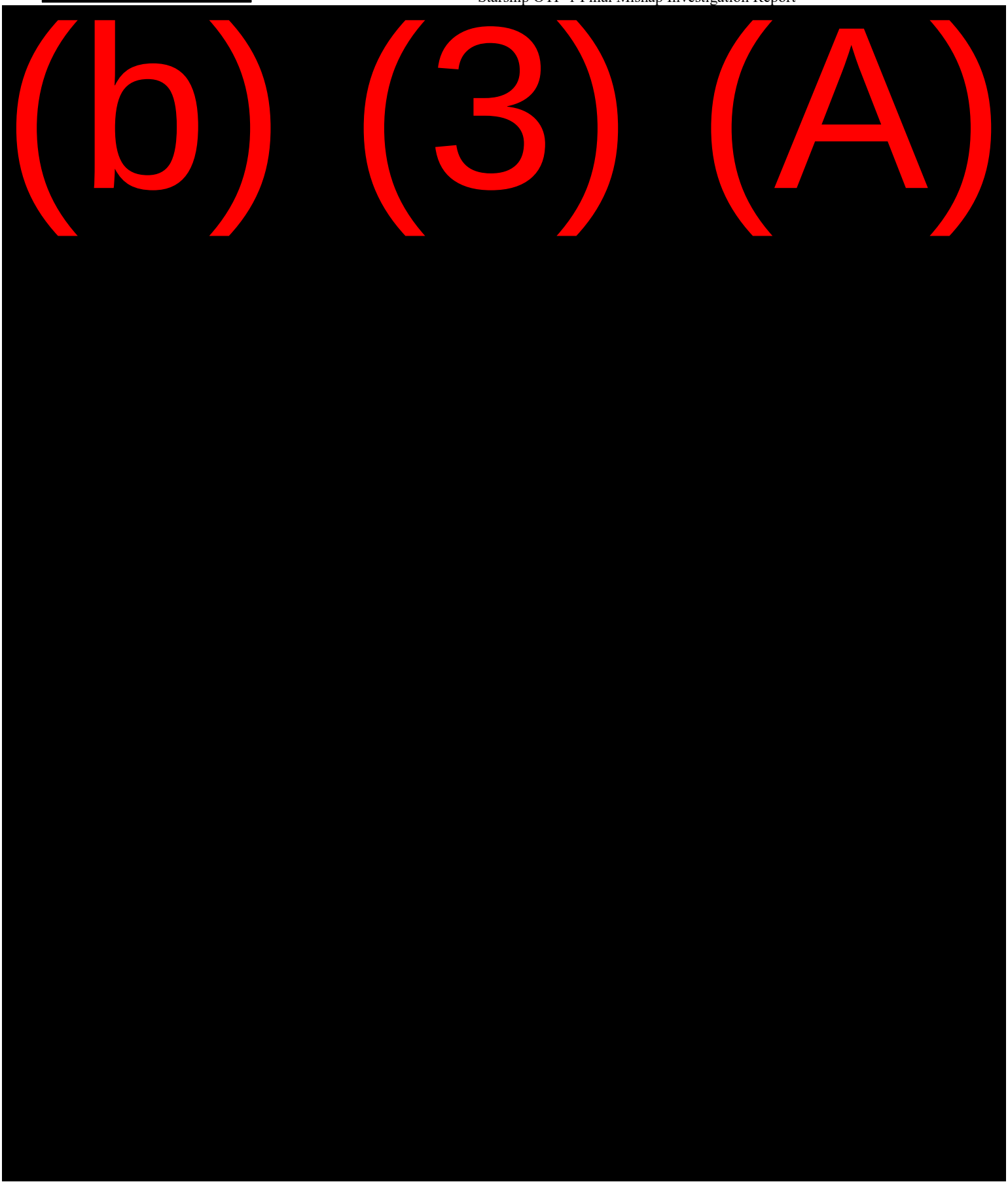

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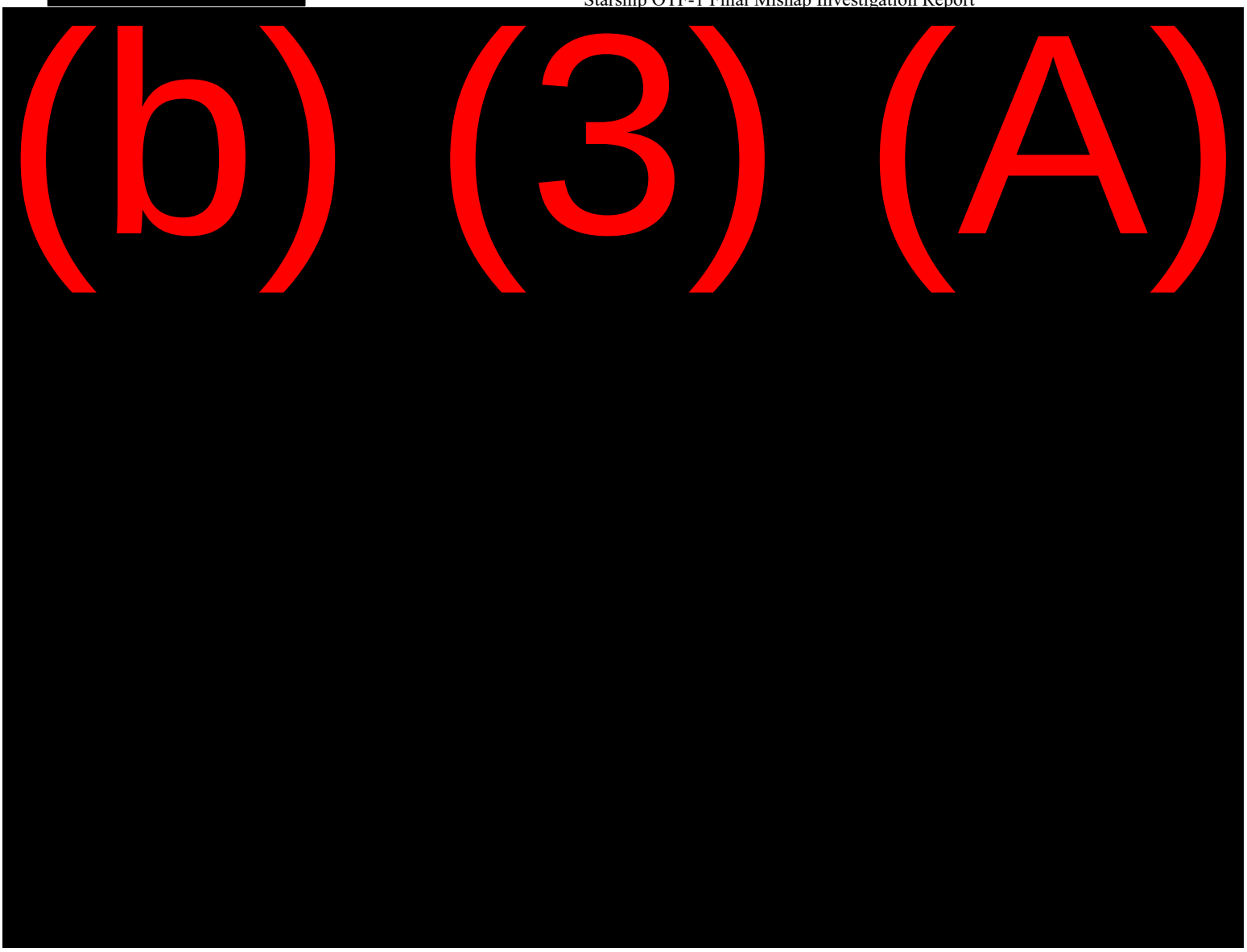

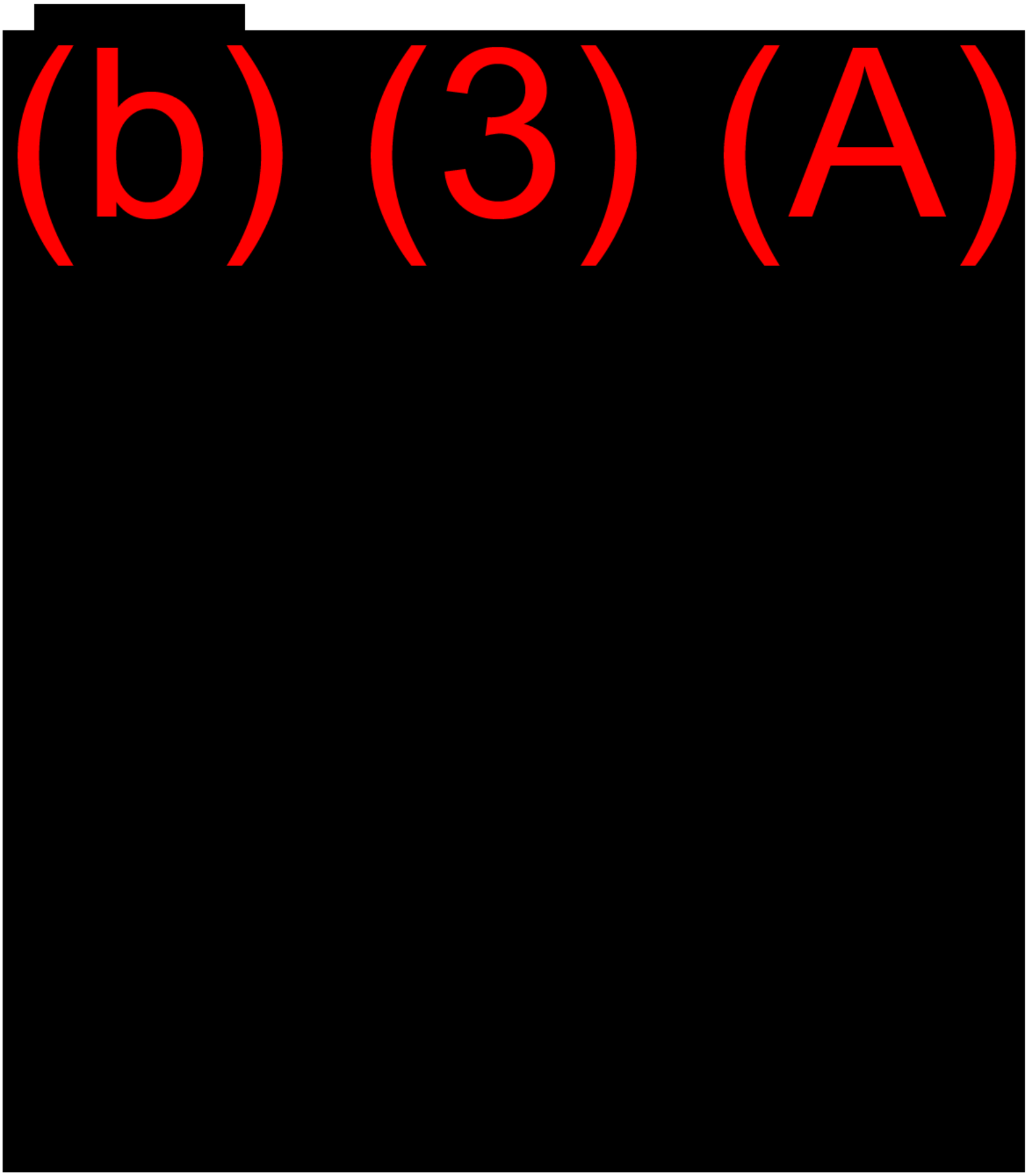

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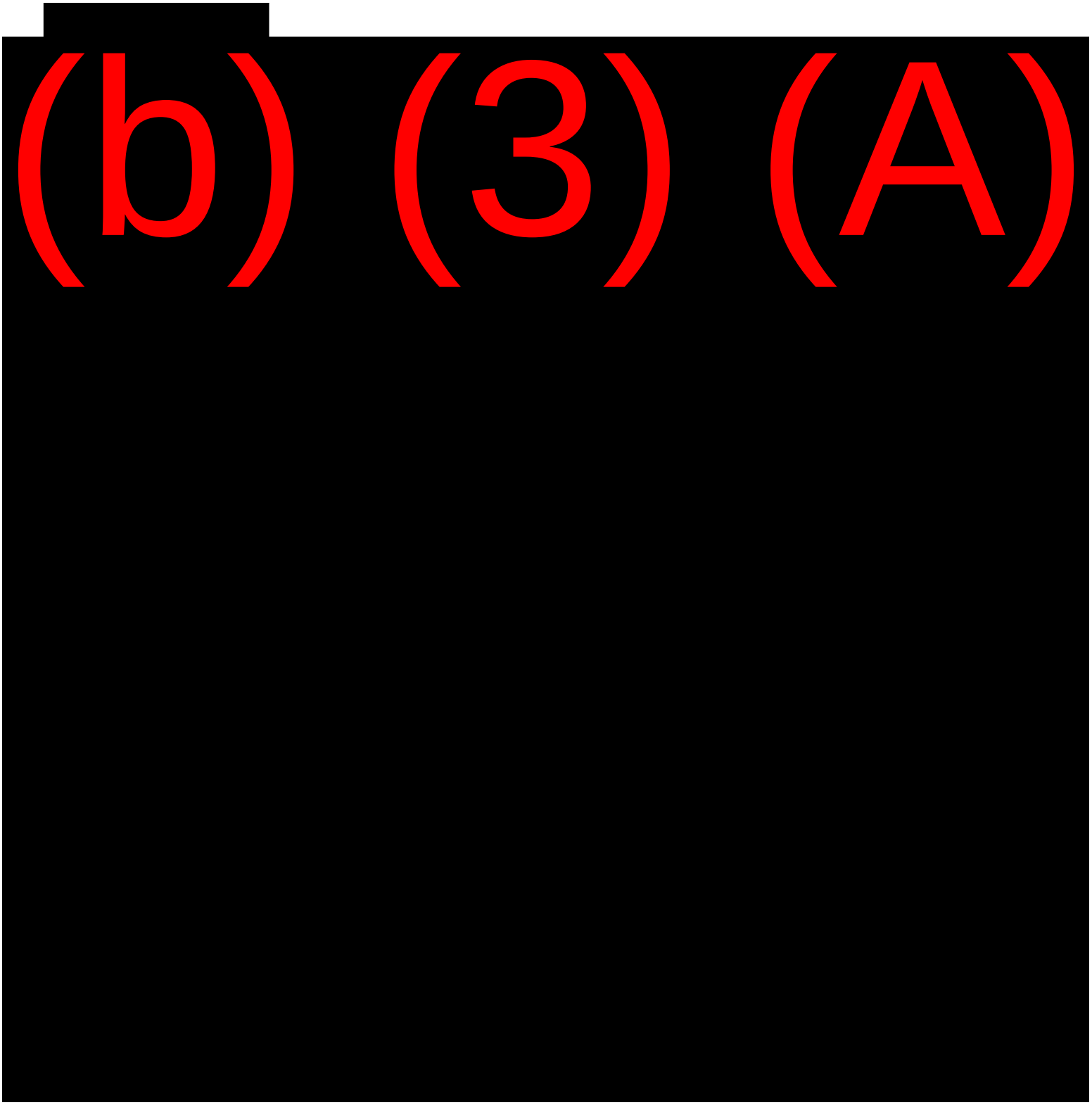

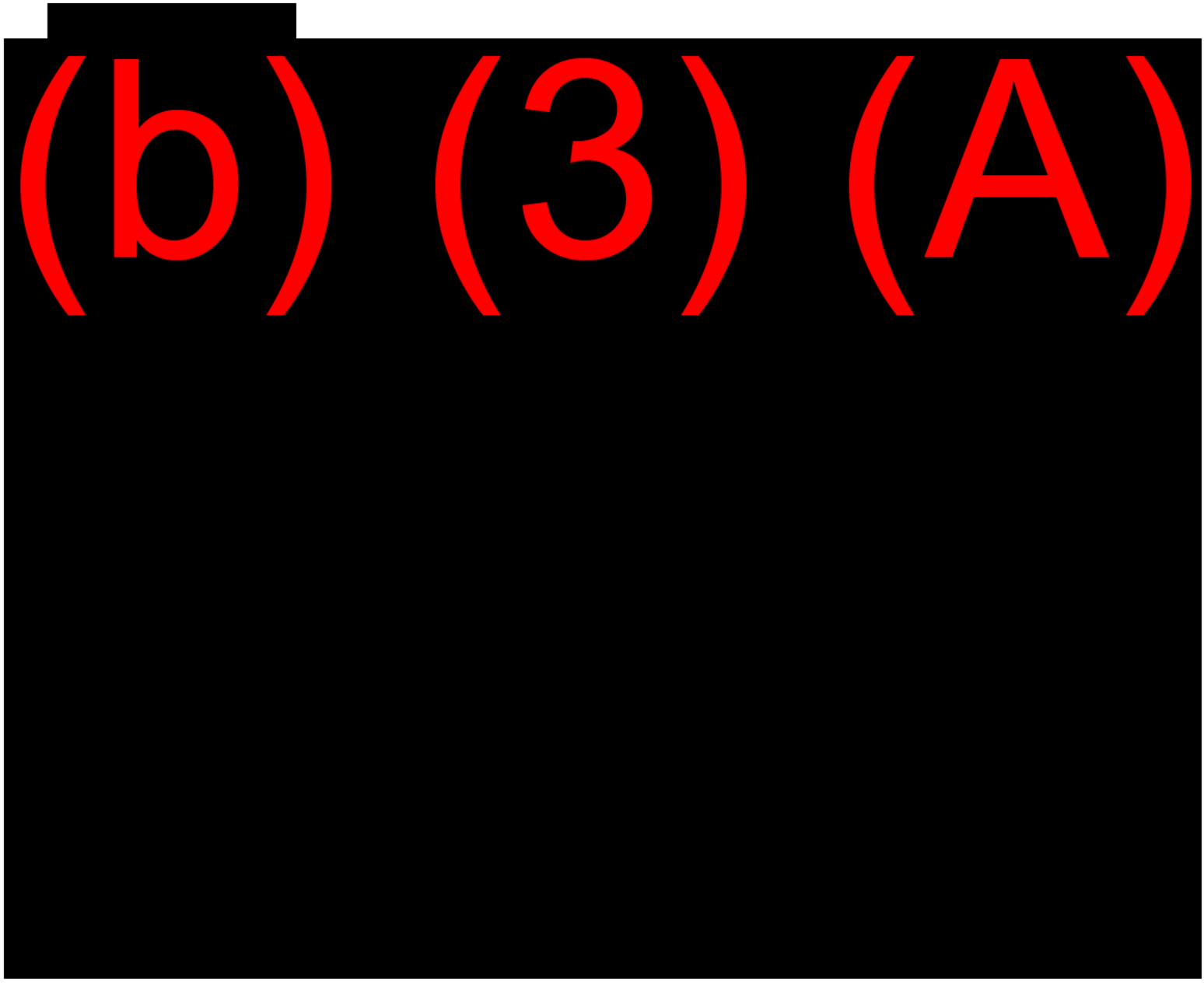

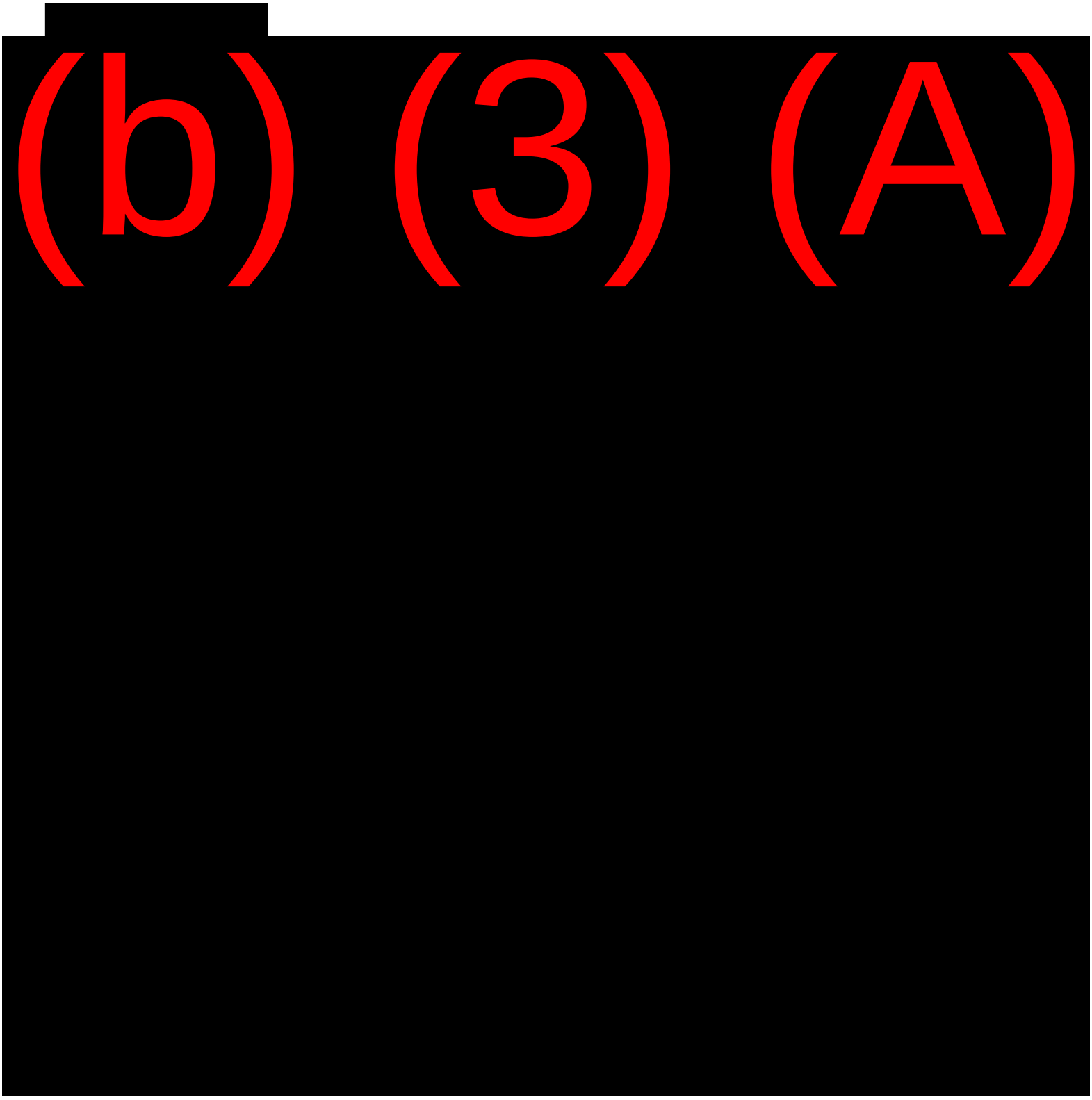

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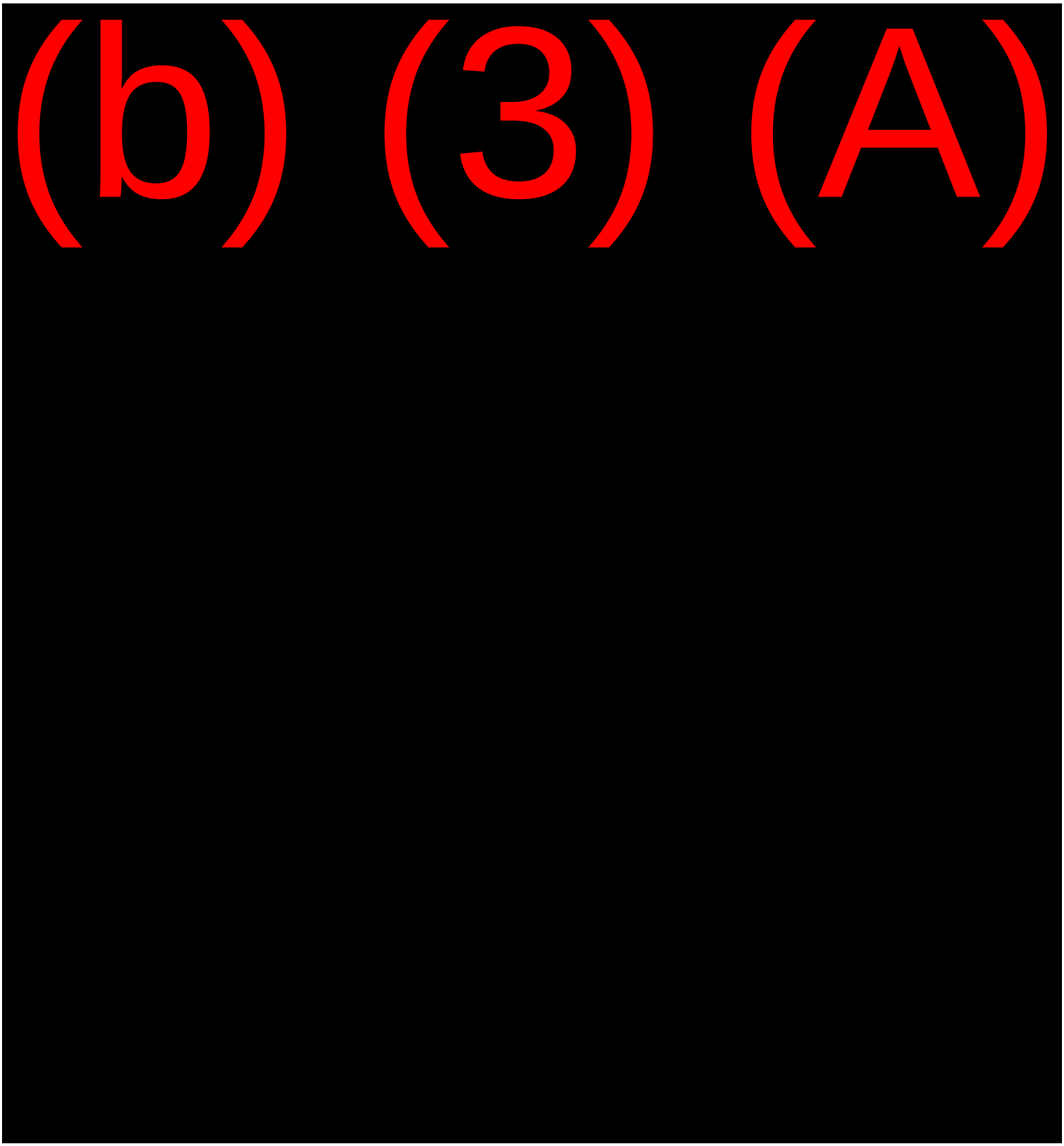
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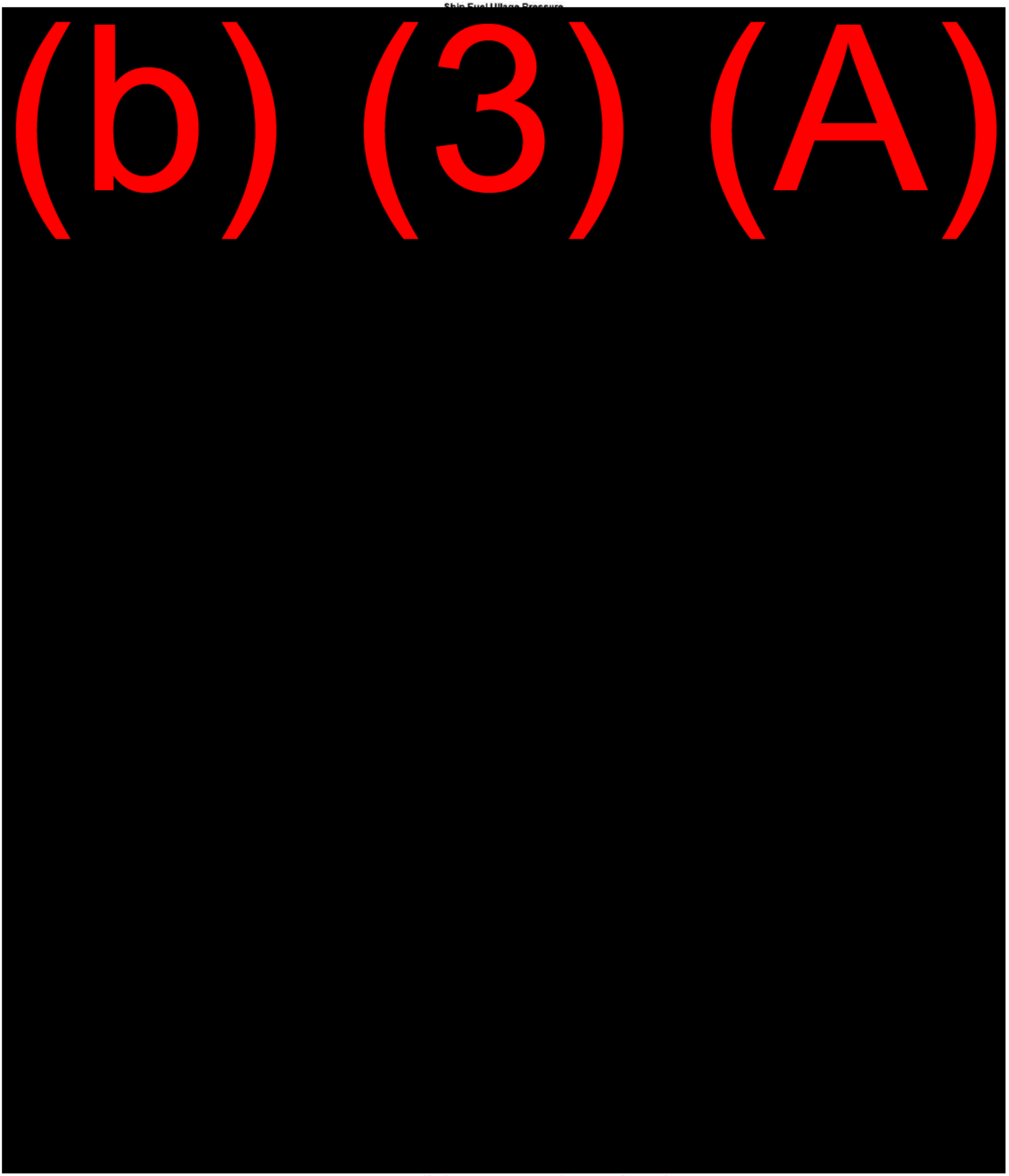
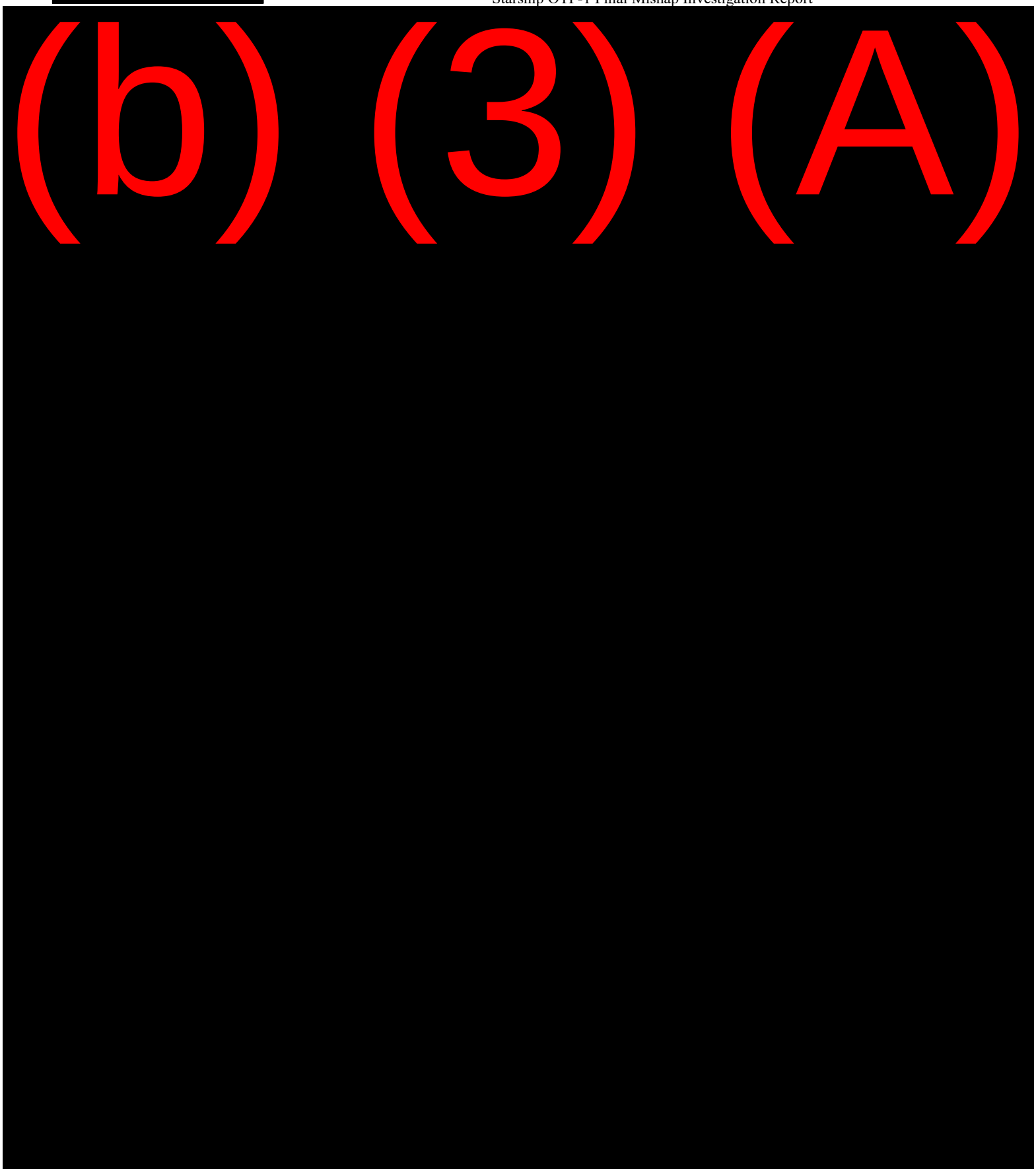
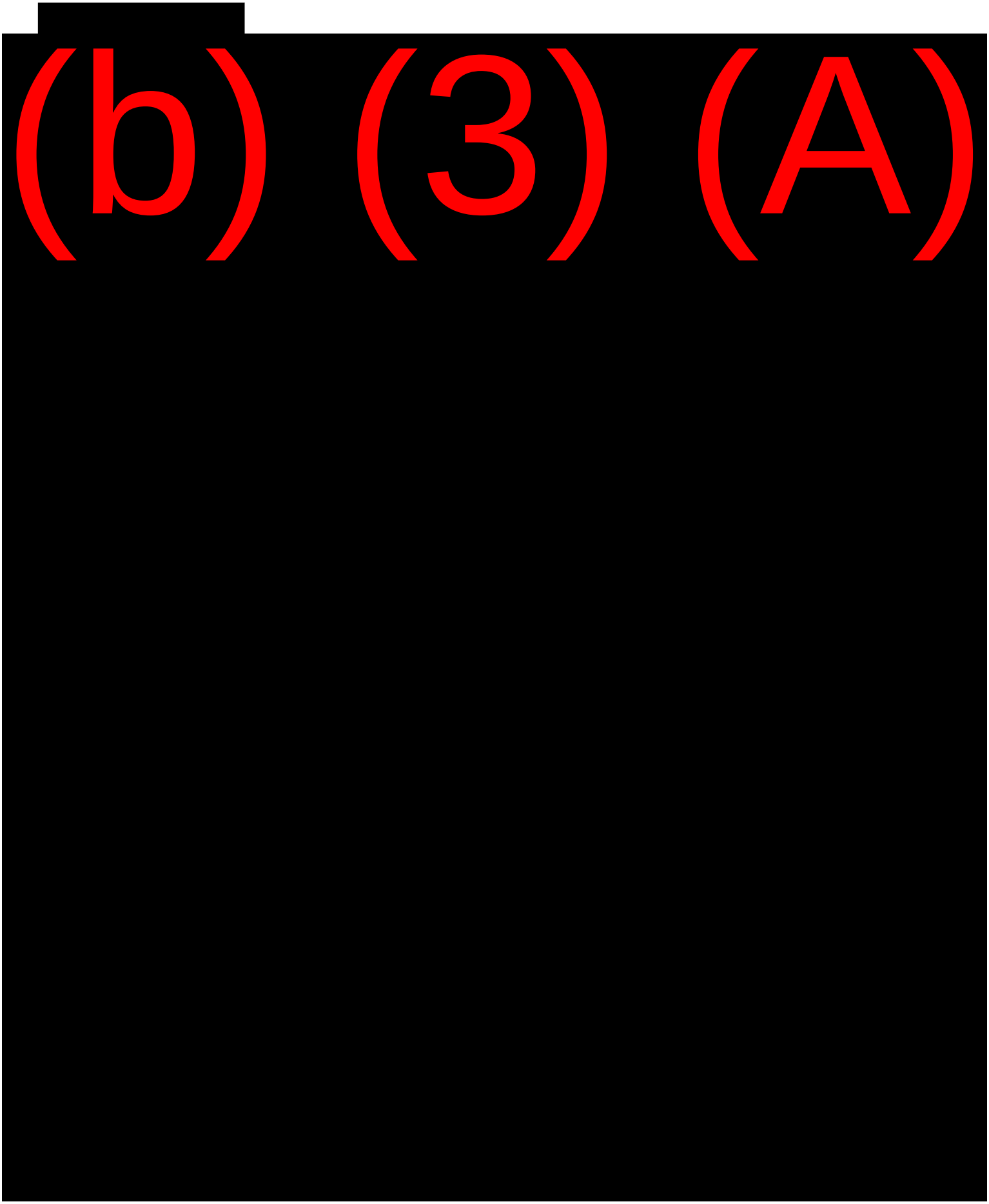
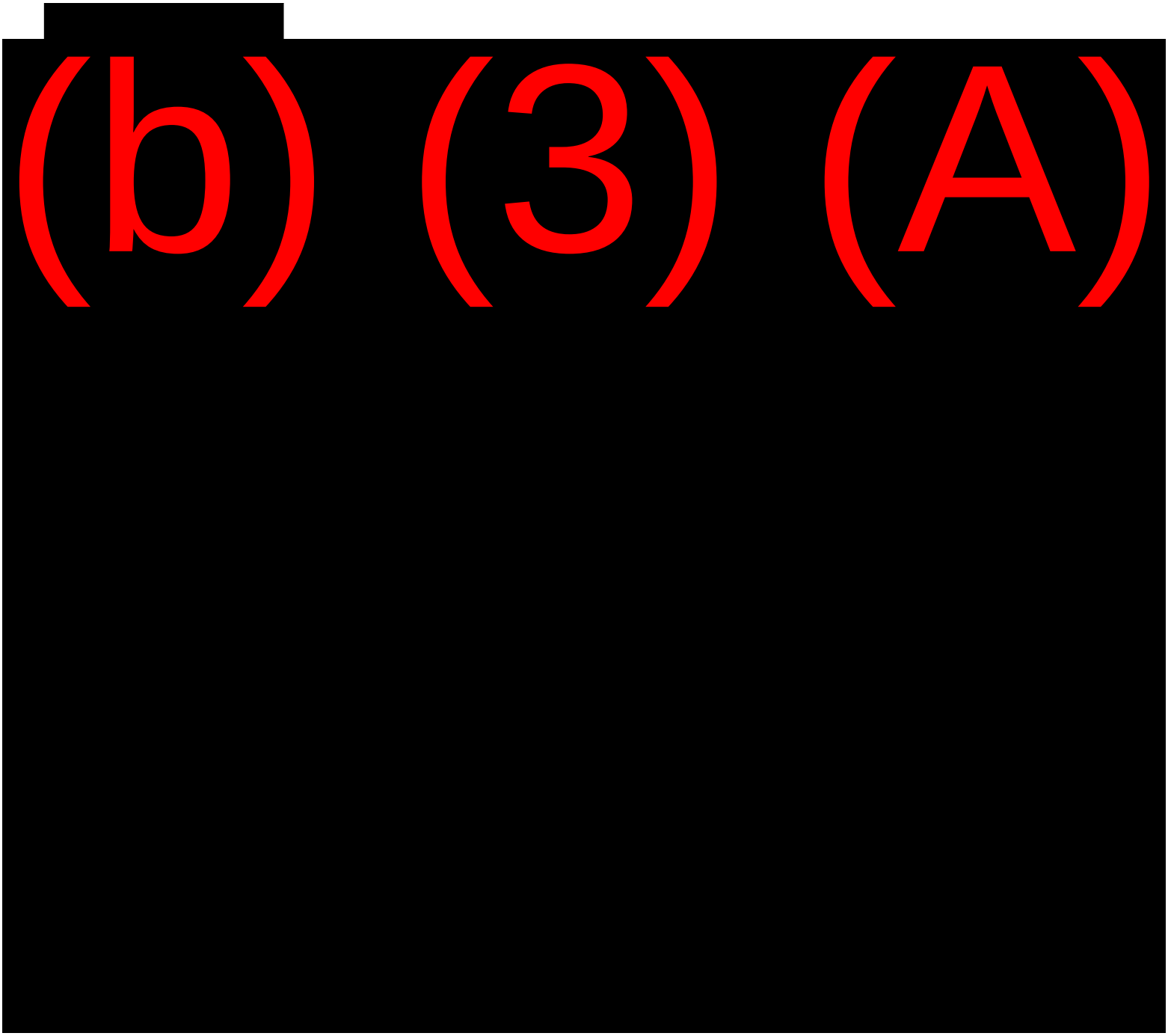
Ship Fuel Ullage Pressure









[redacted]

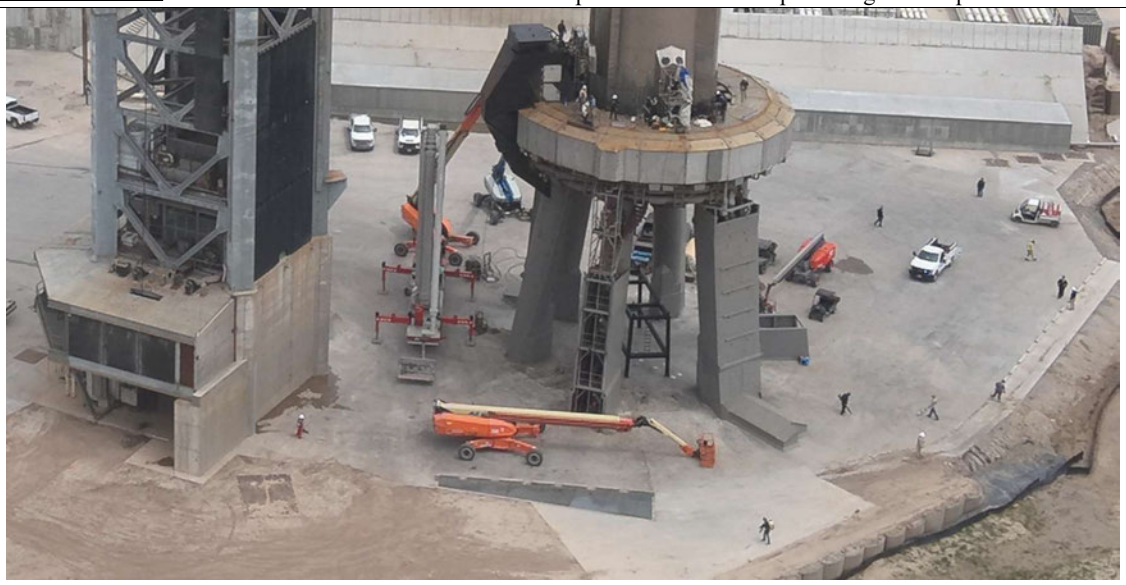
(b) (3) (A), (b) (4)

[redacted]

## 6. Launch Pad Deck Failure

One of the more visible additional observations associated with OTF-1 was the damage to the pad deck under the launch mount (b) (3) (A), (b) (4)

[redacted]



[redacted]

(b) (3) (A), (b) (4)

[redacted]

(b) (3) (A)

[redacted]

(b) (3) (A)

[redacted]

[redacted]

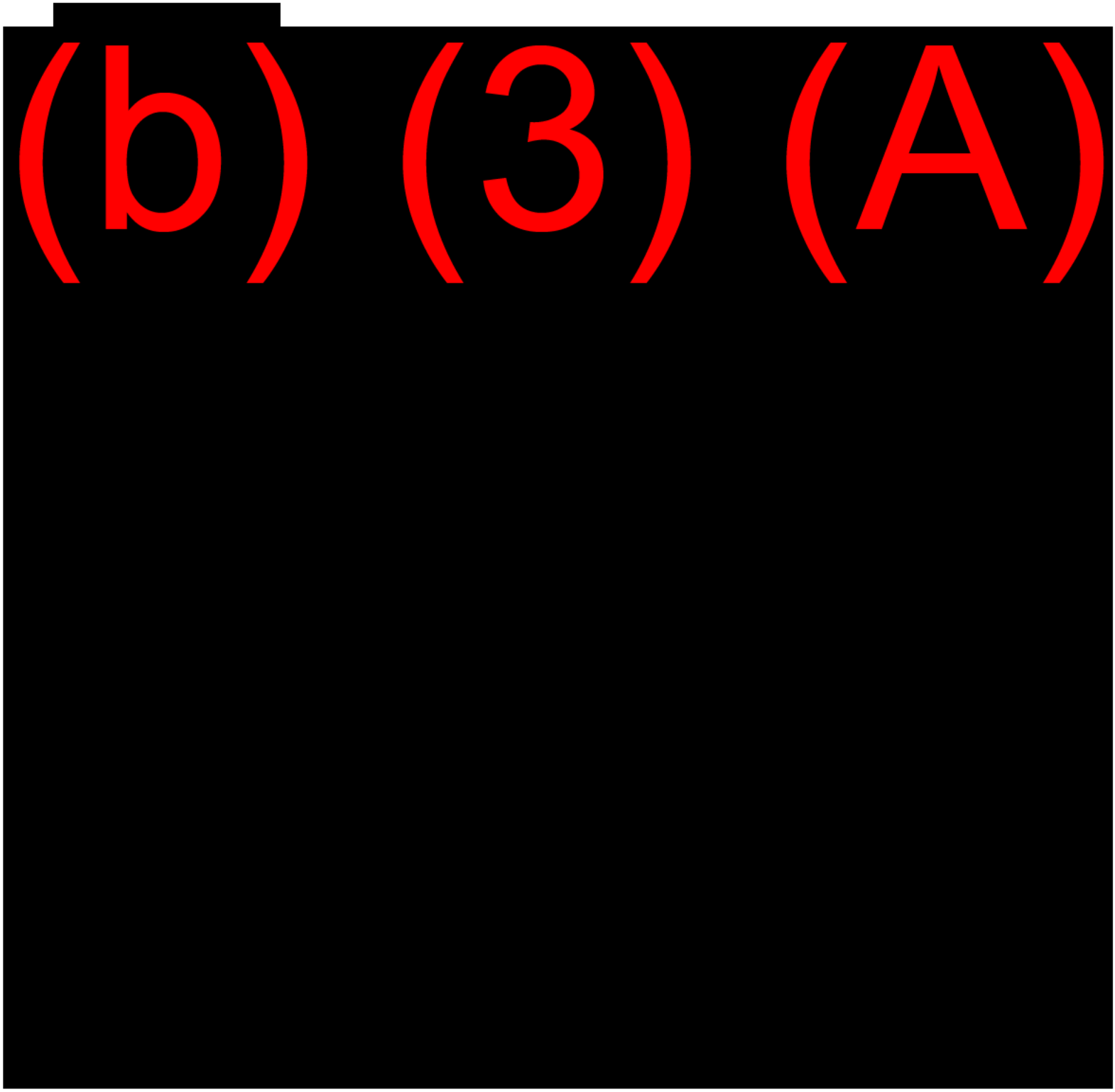
As a result of lessons learned for Starship OTF-1, SpaceX has redesigned the pad deck and foundation (b) (3) (A)

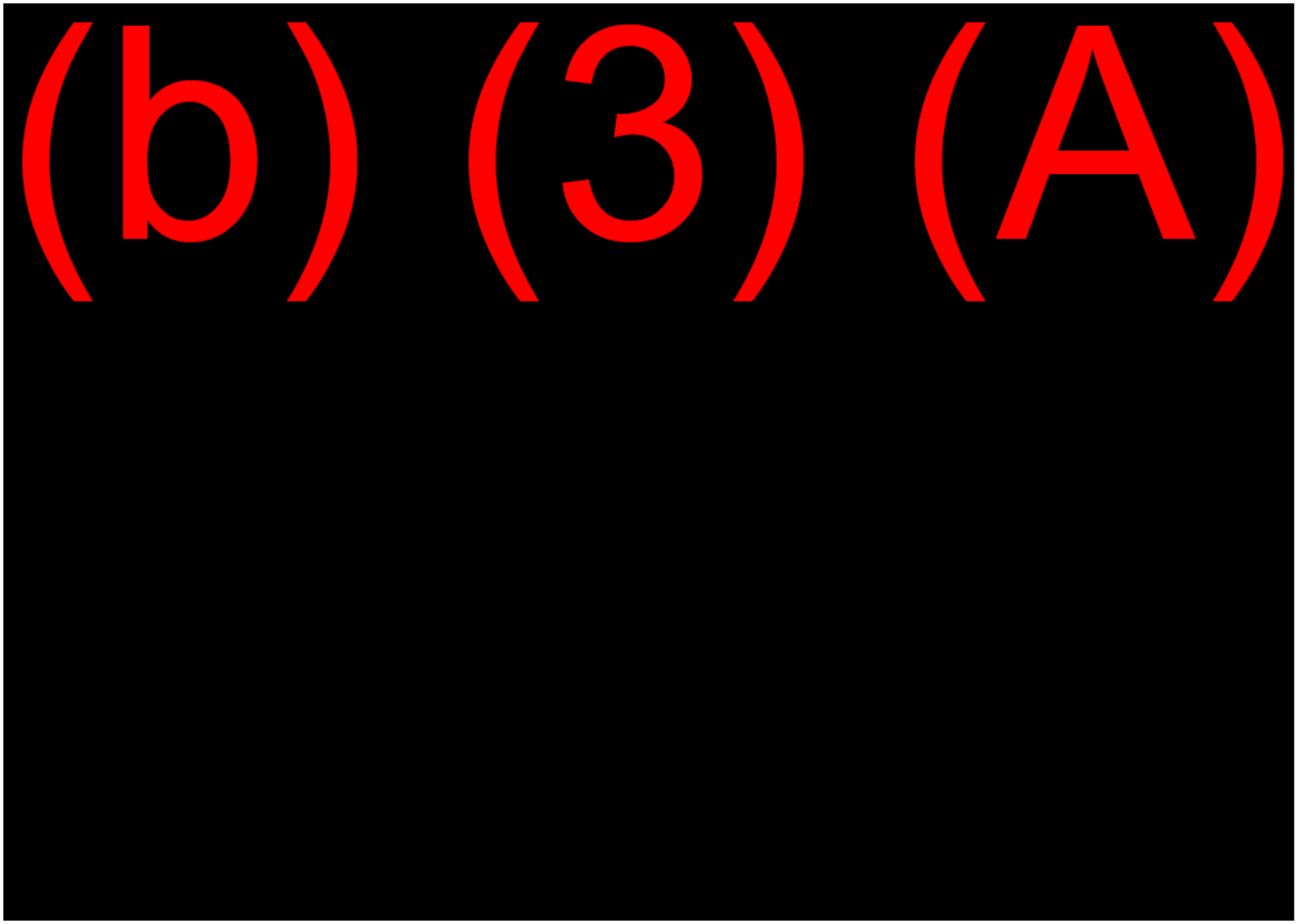
[redacted]

(b) (3) (A), (b) (4)

[redacted]

[redacted]


(b) (3) (A)



[redacted]

(b) (3) (A), (b) (4)

[redacted]

(b) (4)

(b) (4)

[redacted]

(b) (4), (b) (3) (A)

(b) (3) (A) [redacted]


## 7. Summary

(b) (4) [redacted]

The investigation team finds that the Orbital Test Flight 1 mishap was caused by fires and detonations in Booster 7's outer engine bays resulting in aft end fires leading to loss of communication with the majority of the thrust vector control actuators leading to an inability to control the vehicle. This resulted in a vehicle turn, tumble, violation of Chevron 7 rule, and initiation of the vehicle's onboard Automated Flight Safety System (AFSS) terminating the flight. (b) (3) (A) [redacted]

(b) (3) (A) [redacted]

[redacted]
(b) (3) (A)

The vehicle's AFSS system was activated and an unexpected and unacceptably large delay between vehicle destruct charges firing and vehicle demise was observed. Root cause of this failure was design and test shortcomings of this system, and corrective actions have been implemented (b) (3) (A), (b) (4)
[redacted]

# 8. Post Mishap

## 8.1 Post-Mishap Containment

(b) (4)
[redacted]

(b) (3) (A), (b) (4)

(b) (3) (A)

(b) (3) (A), (b) (4)

(b) (3) (A), (b) (4)

(b) (3) (A), (b) (4)

(b) (3) (A), (b) (4)

(b) (4)

[redacted]

(b) (4)

[redacted]

[redacted]

[redacted]

(b) (4)
[redacted]

[redacted]

[redacted]