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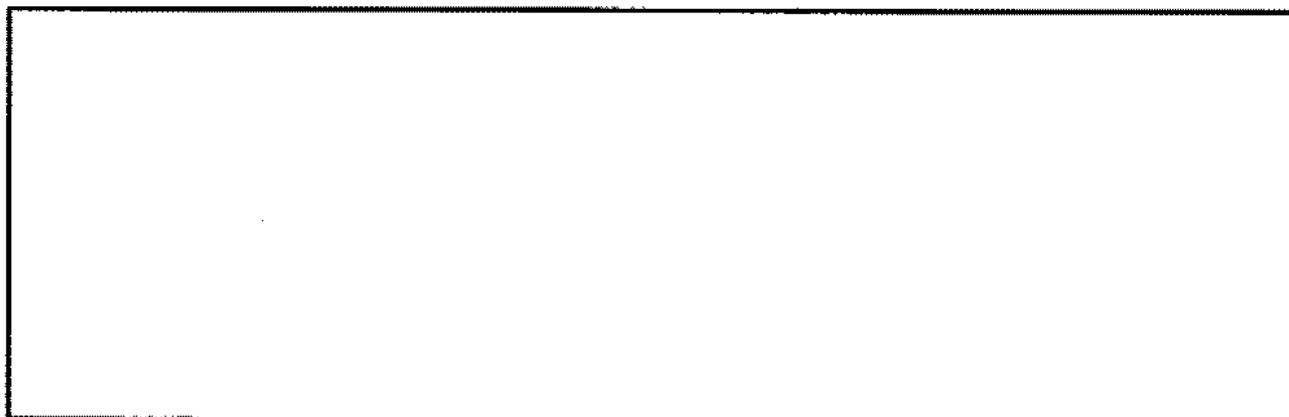
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Missile Defense Agency
Department of Defense



FTG-06a Failure Review Board (FRB) Final Report (U)

9 August 2011



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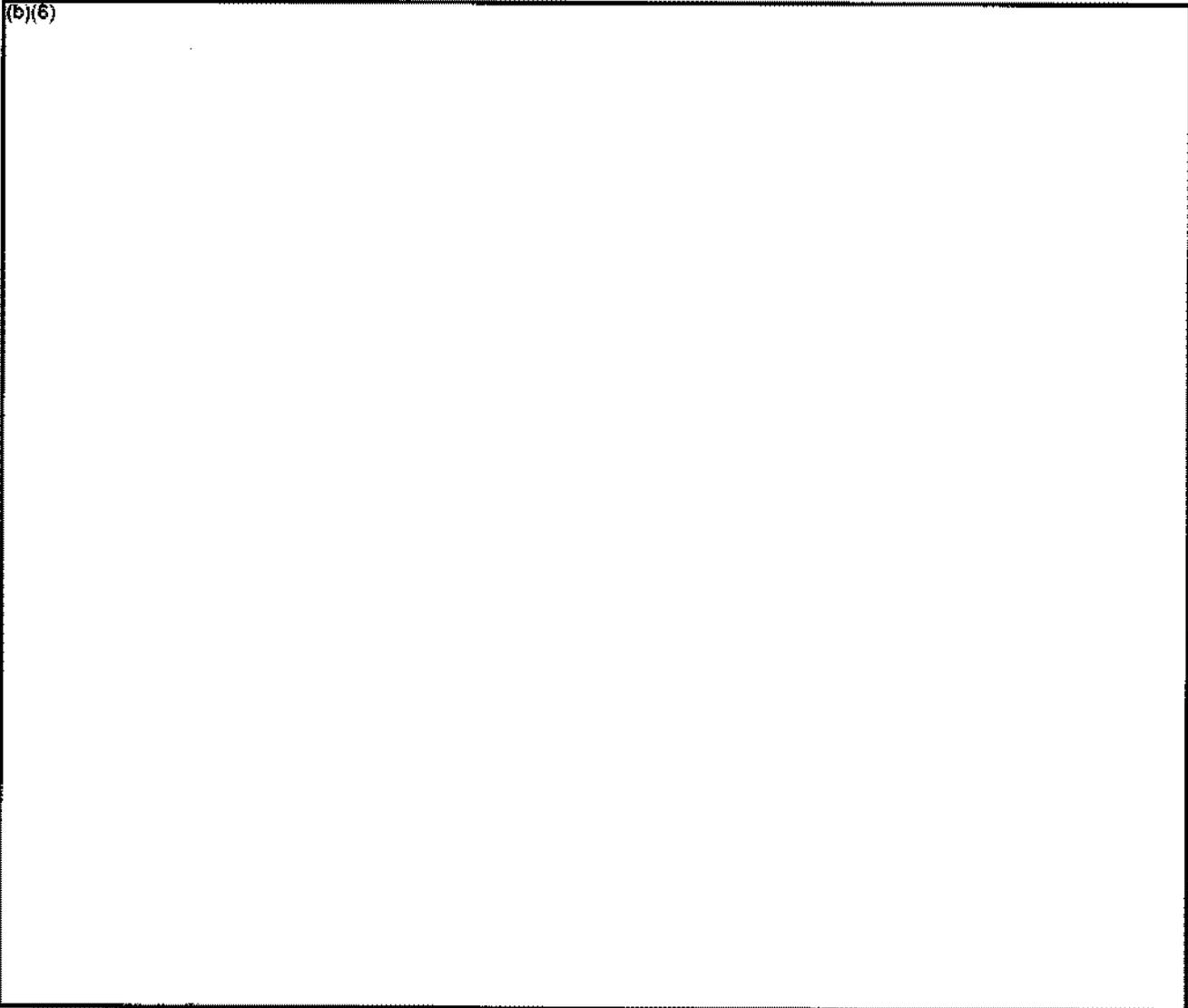
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VERSION	DATE	CHANGE	AFFECTED PAGES
0	1 August 2011	Initial Issue	All
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~~(U)~~ Preface

~~(U)~~ The FTG-06a Failure Review Board (FRB) was activated on 15 December 2010 to (1) investigate and determine the cause of failure, and (2) perform modeling and testing to confirm the failure mode. The team was composed of highly experienced expertise from academic, industry, Federally Funded Research Development Center (FFRDC), and Government personnel.

~~(U)~~ FRB investigative work began on 20 December 2010 in Huntsville, AL and continued on 3 January 2011 in Tucson, AZ at the Raytheon Missile Systems Company, the supplier of the Exoatmospheric Kill Vehicle (EKV) to the Boeing Company. Engineering analysis and testing has been ongoing since that date. The FRB was comprehensively supported by the Boeing Company, Raytheon Company, Northrop Grumman, Aerojet, and Government personnel.

~~(U)~~ The report can be read at a high level for general information and key findings produced through the investigation by reading the Executive Summary as well as the Conclusions located in SECTION 10 in the main body of the report.

~~(U)~~ The files are archived at the Missile Defense Data Center (MDDC) for future reference. The main body and each individual Appendix as listed in SECTION 11 are provided as unique data products for easy checkout and reference.

~~(U)~~ The complete report is classified ~~SECRET~~.

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EXECUTIVE SUMMARY

(S) Presented herein is the FTG-06a Failure Review Board's (FRB) finding of the root cause of failure to intercept the target. This finding was determined after closure of all boxes on the FRB approved Fault Tree. The details, analysis, testing, and evidence used to close each box of the Fault Tree is contained in the "FTG-06a Failure Review Board (FRB) Final Report". The IMU configuration for this test was Capability Enhancement (CE)II. This Executive Summary will focus on the root cause and the data supporting this finding.

(S) FTG-06a Mission Events

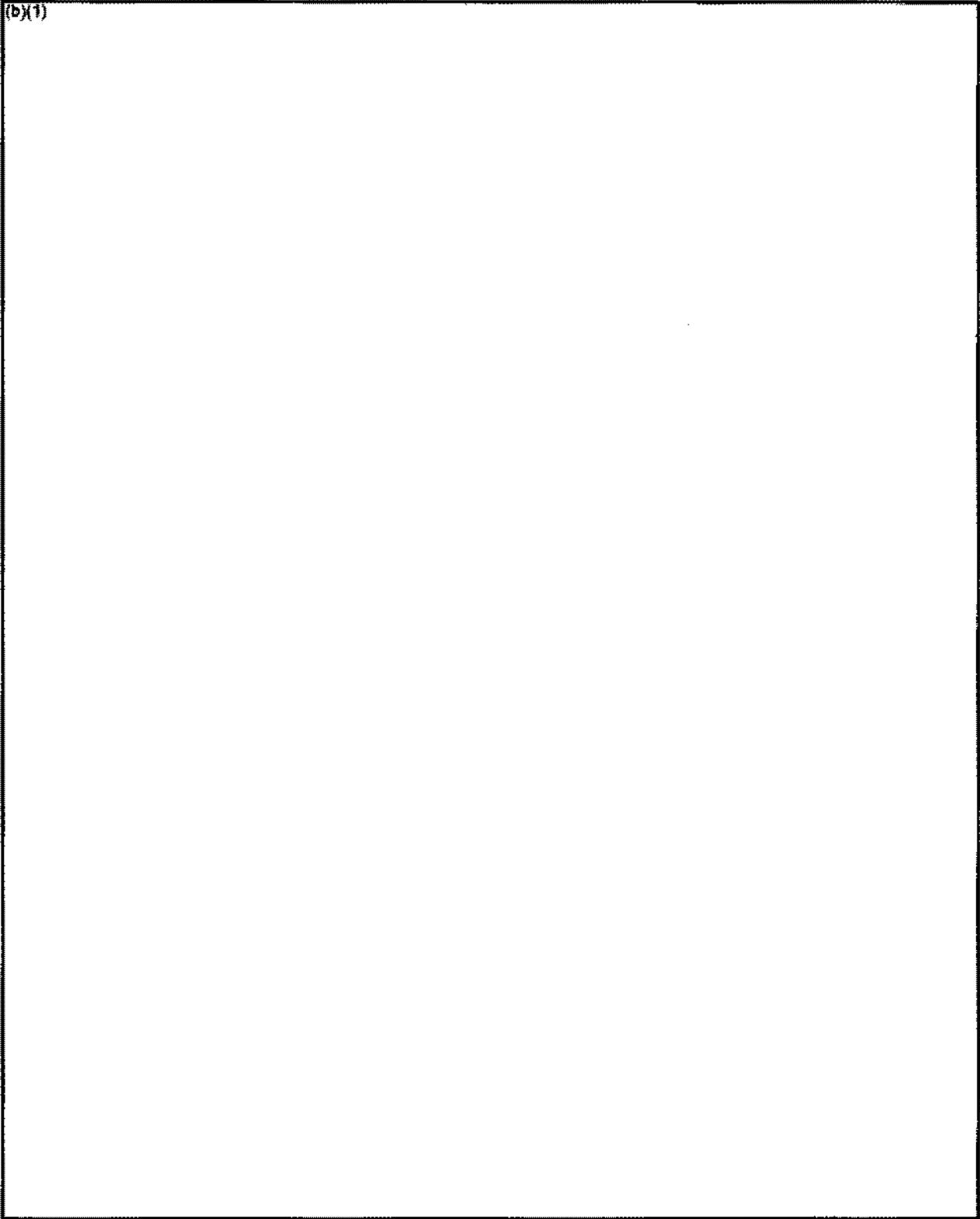
(S) The FTG-06a target (LV-2) successfully launched and performed nominally on all required events to generate the target scene.

(b)(1)

(b)(1)

~~(S)~~ Failure Event Sequence

(b)(1)



(b)(1)

(b)(1)

(b)(1)

(U) The Failure Review Board

(U) Upon completion of the test, the Failure Response Team (FRT) was convened in place at the Missile Defense Integrated Operations Center (MDIOC). The FRT froze all test assets, both hardware and software, and all test data, including recorded data and logs. They examined all available data sources and built initial fault trees. On 15 December 2010, following the initial data review of the mission, the FRT recommended to the Missile Defense Agency (MDA) Director that he activate the Failure Review Board (FRB) to examine the failure with specific focus on the EKV. The FRB was established and the direction to the team included, "...investigating all potential target, interceptor, ground systems, and any other area deemed relevant in the determination of root cause and contributing conditions associated with the FTG-06a failure to intercept" and to "...determine and confirm the root cause(s) of the mission failure." The EKV portion of the FRB investigation was located in Tucson, AZ.

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(b)(1),(b)(3) 10 USC §130

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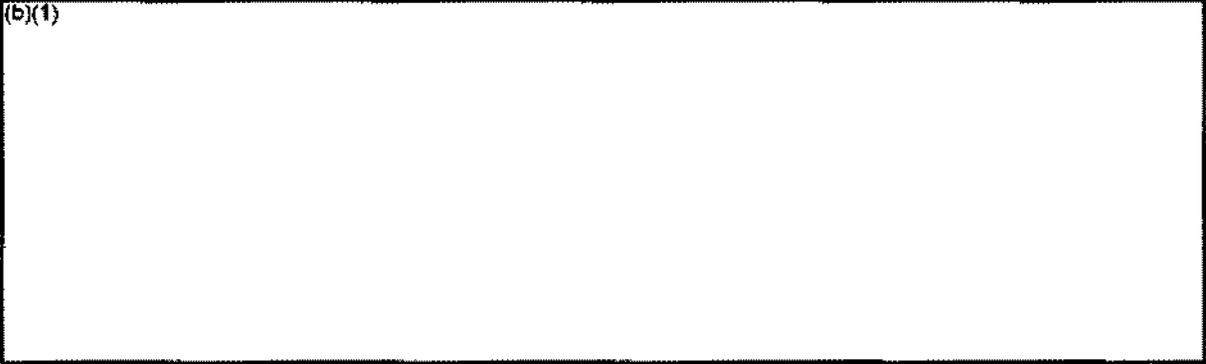
FAILURE REVIEW BOARD FINAL REPORT (U)

SECTION 1. (U) FTG-06A TEST OVERVIEW

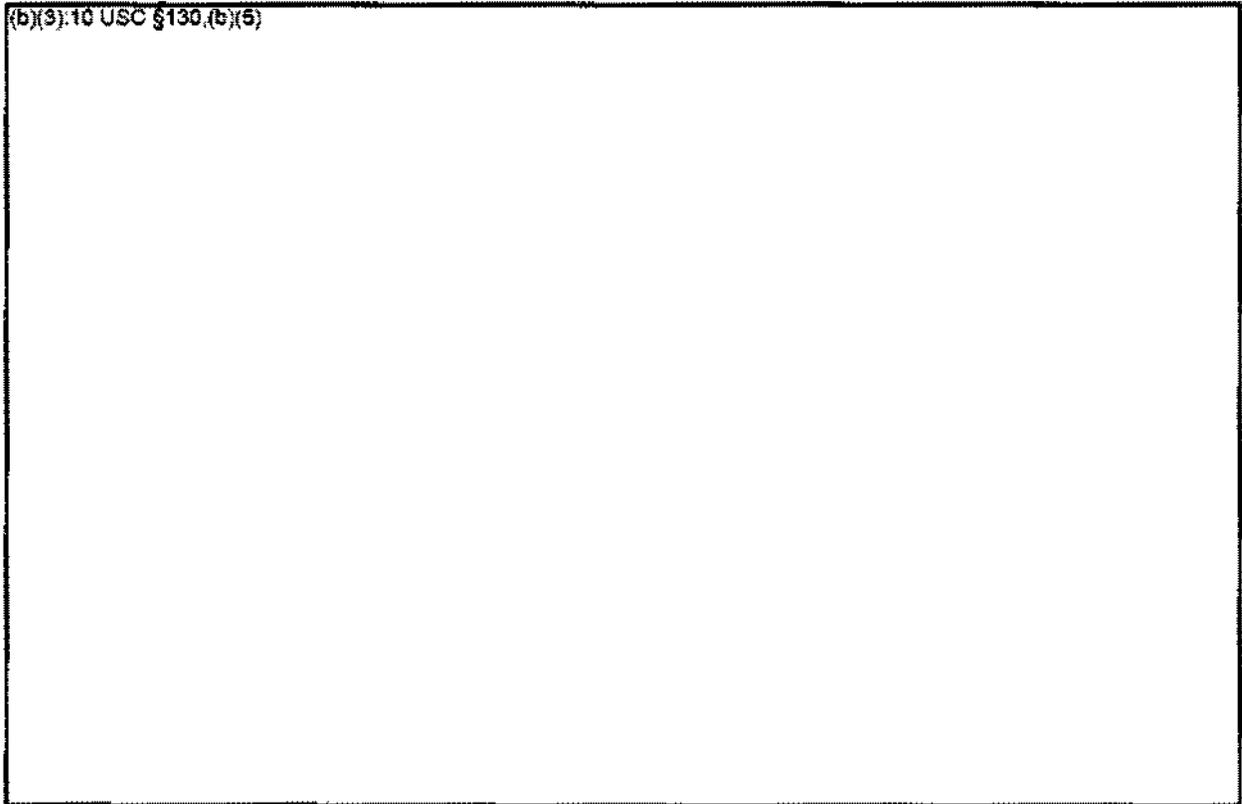
1.1. (U) TEST EXECUTION

1.1.1. (U) Test Events

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(b)(3); 10 USC §130,(b)(6)

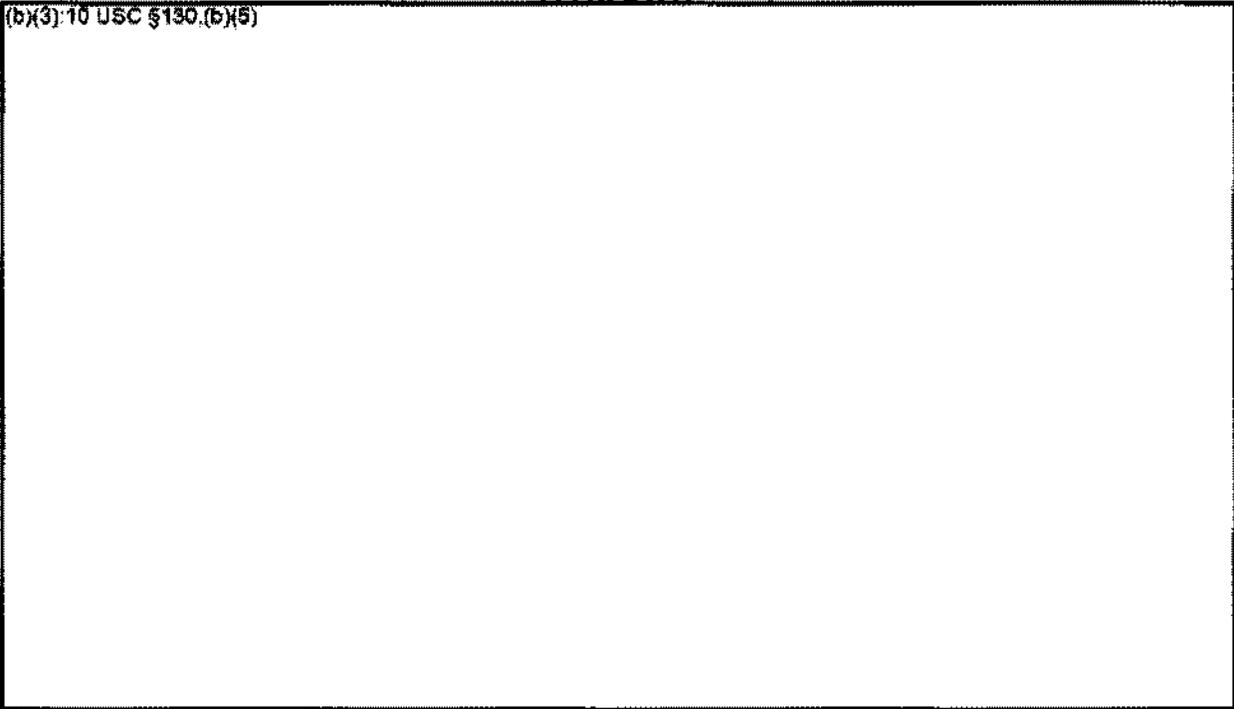


(U) Numerous GMD Component Integration Tests, Risk Reduction Integration Tests, Countdown Training (CDT) sessions, Readiness Tests and other checkout activities were conducted prior to the flight test. These activities ensured all systems were functioning as required and personnel were properly trained to execute the FTG-06a mission. The CDT sessions were conducted within the timeline of the planned countdown and allowed realistic nominal, off-nominal, and contingency training to be conducted.

(U) Several Ballistic Missile Defense System (BMDS) Test Incident Reports (BTIRs) were generated during these checkout activities, with all BTIRs closed or boarded by the Mission Readiness Working Group as low and/or acceptable risks for the mission prior to launch (See Figure 1-2)

**FTG-06a Execution Readiness Events
BTIRs (U)**

(b)(3); 10 USC §130.(b)(5)



1.1.2. (U) Test Objectives Not Met

(U) Post mission analysis indicated the assessment of primary and secondary test objectives as follows:

- (U) Primary test objective #1 3 of 6 met; 2 of 6 partially met
- (U) Primary test objective #2 10 of 10 met
- (U) Secondary test objective 15 of 16 met

(U) Figure 1-3, outlines the assessment of primary and secondary objectives, while Figure 1-4 and Figure 1-5 outline the methodology for assessment of the primary objectives.

(U) Table 1-1 and Table 1-2 depict primary and secondary Critical Engagement Condition (CEC)/Empirical Measure Event (EME) scoring.

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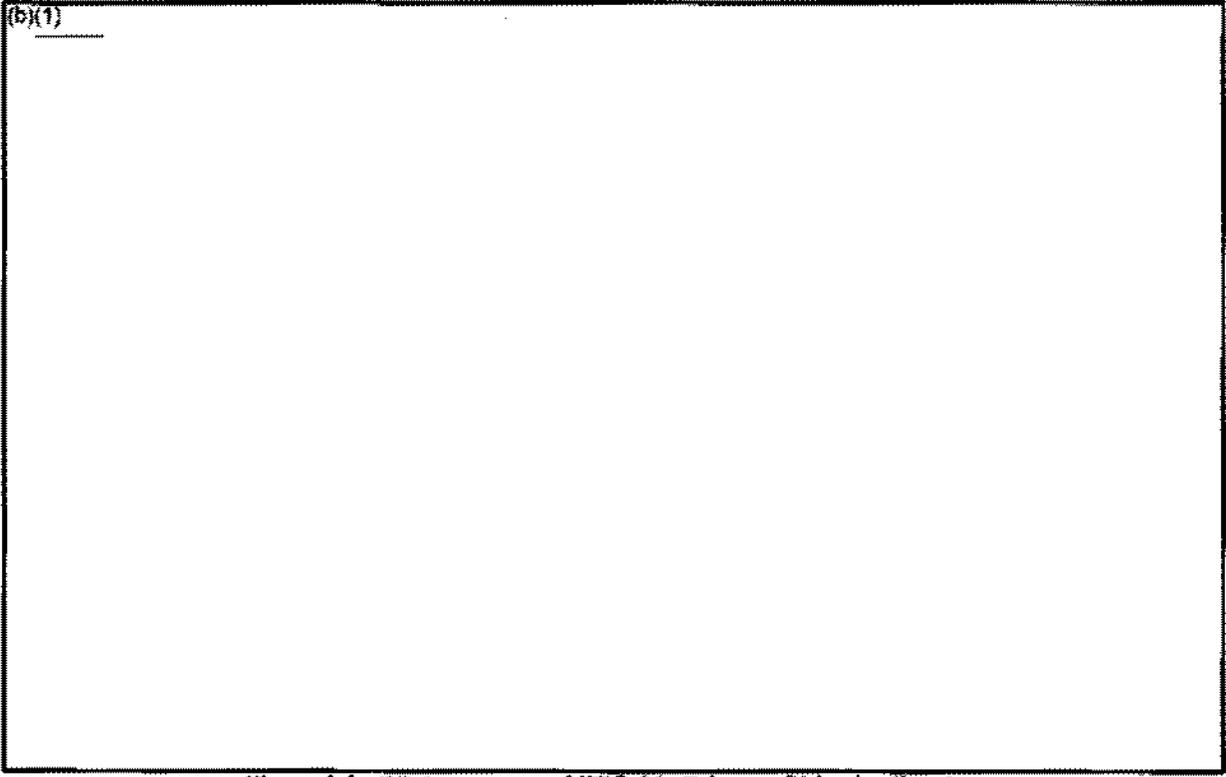


Figure 1-3. (b) Assessment of FTG-06a Primary Objective Results

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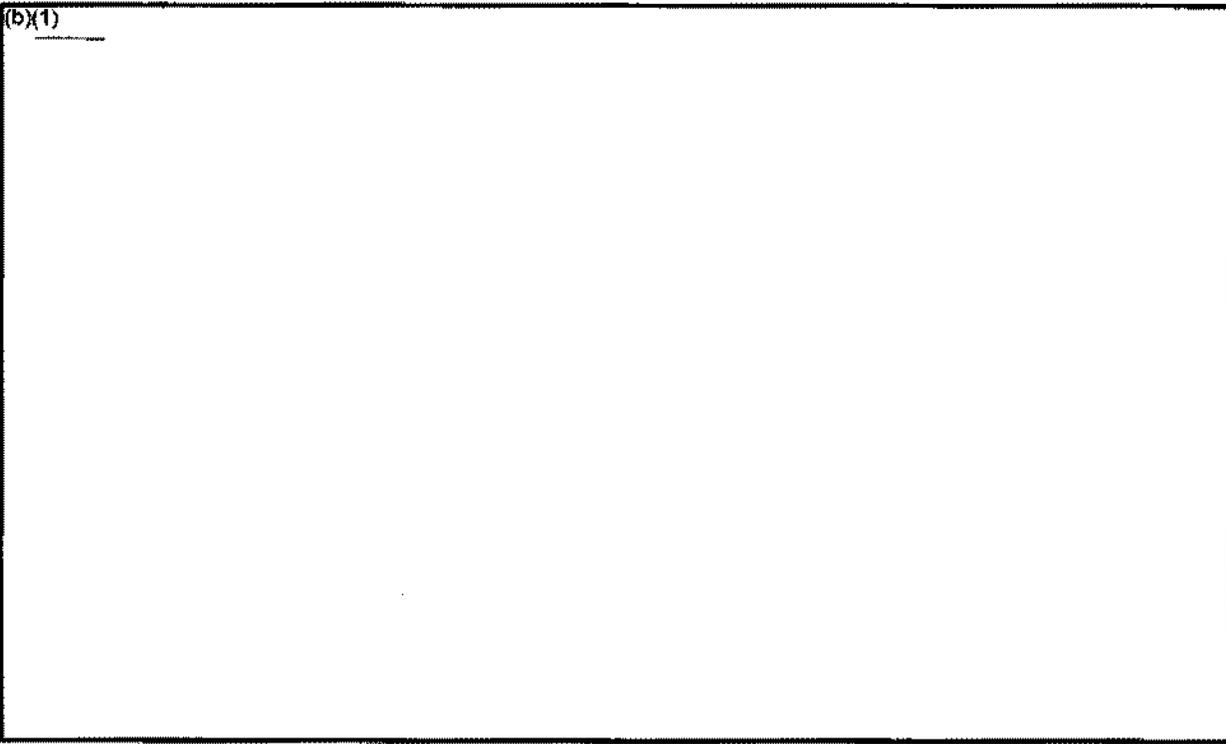


Figure 1-4. (b) Primary Objective #1

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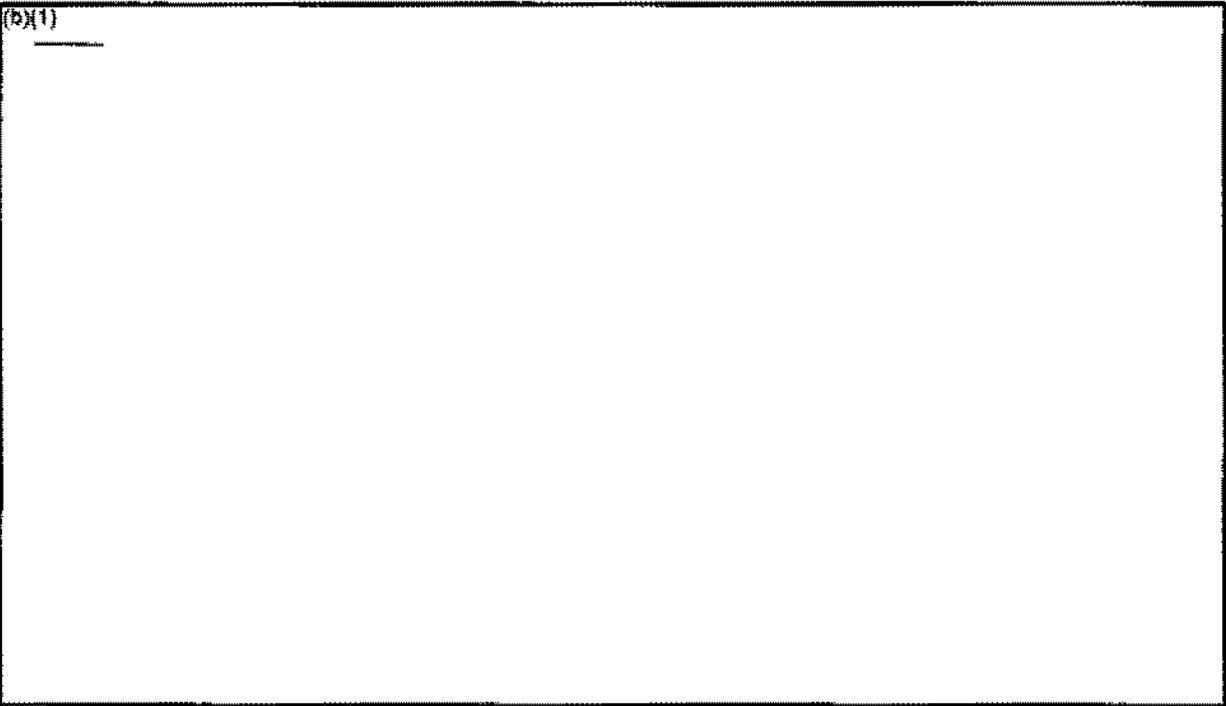


Figure 1-5. ~~(b)~~ Primary Objective #2

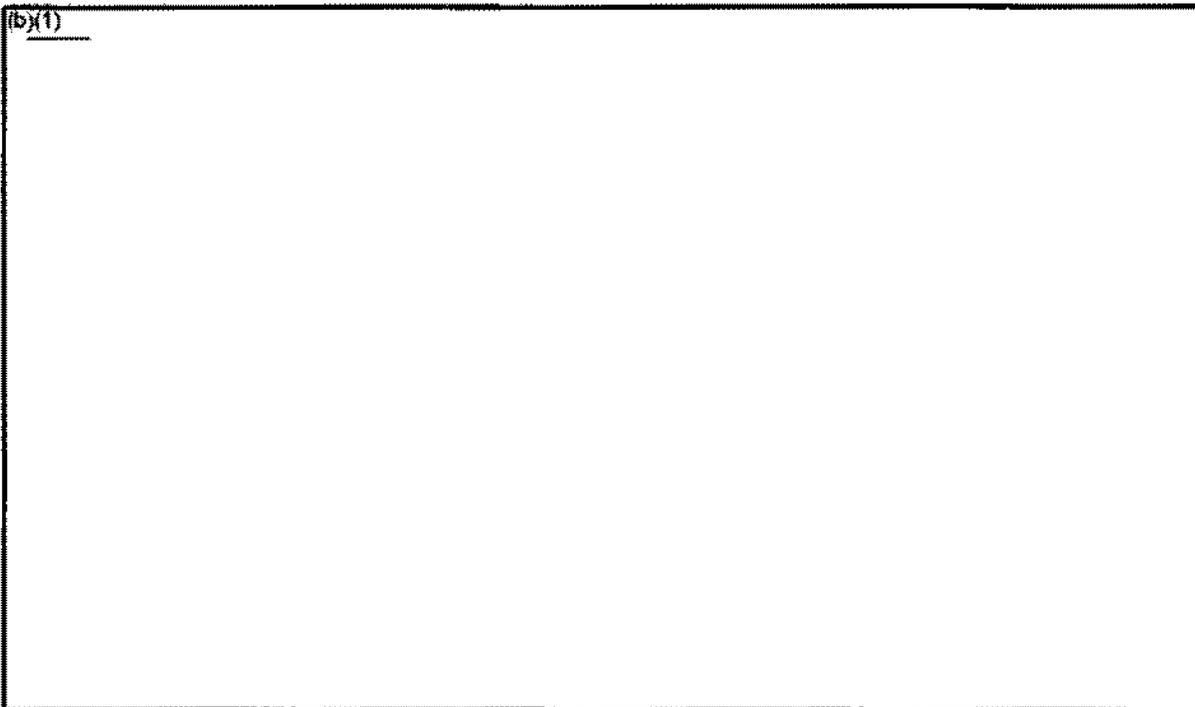
Table 1-1. ~~(b)~~ FTG-06a Primary and Secondary CEC/EME Scoring

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A large rectangular redacted area covering the content of Table 1-1. The area is completely blank, indicating that the information has been removed for security reasons.

Table I-2. ~~(S)~~ FTG-06a Primary and Secondary CEC/EME Scoring

(b)(1)



(b)(1)



1.1.3. ~~(S)~~ Failure Response Team Actions

(U) In accordance with the FTG-06a BMDs Failure Response Plan, dated 10 November 2010 located in Appendix B, the Failure Response Team (FRT) convened immediately after the mission based on the failure to achieve the primary objective and some secondary objectives as outlined in the Test Objective Memorandum (TOM), Appendix E. All test participants were directed to secure all recorded data, maintain configuration, and standby for data distribution instructions and “break of configuration” direction.

1.2. ~~(S)~~ FAILURE INVESTIGATION

1.2.1. ~~(S)~~ Terms of Reference

(U) Formal, independent failure investigation activities began on 20 December 2010 in Huntsville, AL, by the Failure Review Board (FRB) Panel directed by the FRB charter. The FRB was directed to focus all efforts on determining the precise root cause of the failure to intercept and to:

- ~~(S)~~ Develop and coordinate for approval a consolidated failure investigation event schedule and battle rhythm that includes FRB and MDA activities
- ~~(S)~~ Execute a thorough and structured root cause investigation into observations contributing to the failure to intercept
- ~~(S)~~ Confirm through appropriate means that root cause has been determined

- ~~(U)~~ Provide a consolidated final report that identifies root cause
- ~~(U)~~ Augment the core staff as required with the best talent available to execute the terms of reference

~~(U)~~ Based on its findings of fact, the FRB was chartered to record observations which did not contribute to failed primary or secondary objectives in FTG-06a, but which may affect the success of future tests.

~~(U)~~ The FRB was led by the FRB Chairman (b)(6) Other FRB membership consisted of:

- (b)(6) MIT/Lincoln Labs
- (b)(6) MDA, Quality
- (b)(6) Chief Engineer National Systems Projects
- (b)(6) MDA, Chief Engineer GMG
- (b)(6) Davidson Technologies, CEO
- (b)(6) Raytheon, VP Engineering
- (b)(6) MDA, Engineering Test and Verification
- (b)(6) MIT/Lincoln Labs
- (b)(6) Nestlerode Engineering Inc., SME for Thrusters,
- (b)(6) MDA, Career Development Protégé
- (b)(6) Aerospace Corp, SME for IMU
- (b)(6) Boeing, GMD Systems Analysis
- (b)(6) Raytheon, Mission Assurance

1.2.2. ~~(U)~~ Failure Review Board Process

1.2.2.1. ~~(U)~~ Configuration Freeze

~~(U)~~ When activated, the FRB immediately directed a configuration freeze for all components. No configuration changes were to be made without concurrence of the FRB. This ensured that test participant configuration changes did not affect the ability of the FRB to establish and confirm root cause. This freeze applied to both hardware and software.

~~(U)~~ The FRB also controlled allocation of hardware which may be required for any testing planned to assist in root cause confirmation. No hardware, test asset, or siblings of those items were allowed to be used for any test/experiment without the express consent of the FRB chair. This ensured availability of hardware for testing as determined necessary through the root cause confirmation process.

1.2.2.2. ~~(U)~~ Collection and Analysis of Data

~~(U)~~ The FRB polled the test community for all data recorded during the event and ensured data products were catalogued and made available for the FRB and analysts as required. The FRB worked with the industry team of experts to analyze all available test data, summaries and briefings relative to the FTG-06a mission. A detailed mission timeline was developed,

identifying all significant events. Findings of fact and anomalous conditions were recorded and archived. In addition, any observations relative to deviations from nominal performance were recorded and included with the data management archive. All findings of fact, anomaly conditions, and observations were provided to the product teams for consideration in confirming root cause. The observations deemed not relevant to root cause of this investigation were provided to the Director and the MDA Program Manager and the appropriate BMDS components for further study and disposition at the required level.

1.2.3. (S) Fault Tree Description and Methodology

(b)(1)

(S) The FRB recognized early in the investigation that further test data would be required to determine root cause and adjudicate some FTICR boxes. Maximum use of existing test data along with extensive analysis and modeling has been performed to close all FTICR boxes.

(S) The guiding method of the FRB has been to utilize all existing data to hypothesize failure modes, create models to explore those hypotheses and determine how well all the data can be explained. These data models and hypotheses have been used to drive test planning in order to anchor models and prove or disprove the hypotheses. The testing planned and executed was structured to first anchor models and collect data pertinent to the leading hypothesis. An initial series of testing was planned to specifically address required knowledge points to close fault tree boxes. By closing these boxes, it was meant to determine if the box contributed to root cause or was a non-contributor to root cause. As testing proceeded, and results analyzed the FRB drove further testing as required as new knowledge point needs were identified to anchor the modeling. Eighteen total tests were conducted to support the FRB Finding (refer to paragraph 9.6.1 for test descriptions).

(S) Lastly, many of the hypothesized failure mechanisms cross multiple component boundaries in complex interactions. The FRB therefore created a Fishbone diagram to aid in the investigation. It is described in the next section and was also used to create a second scoring approach to differentiate different degrees of failure contribution, also covered in the next section.

1.2.4. (S) Fishbone Description and Methodology

1.2.4.1. (S) Fishbone Motivation

(b)(3); 10 USC §130, (b)(5)

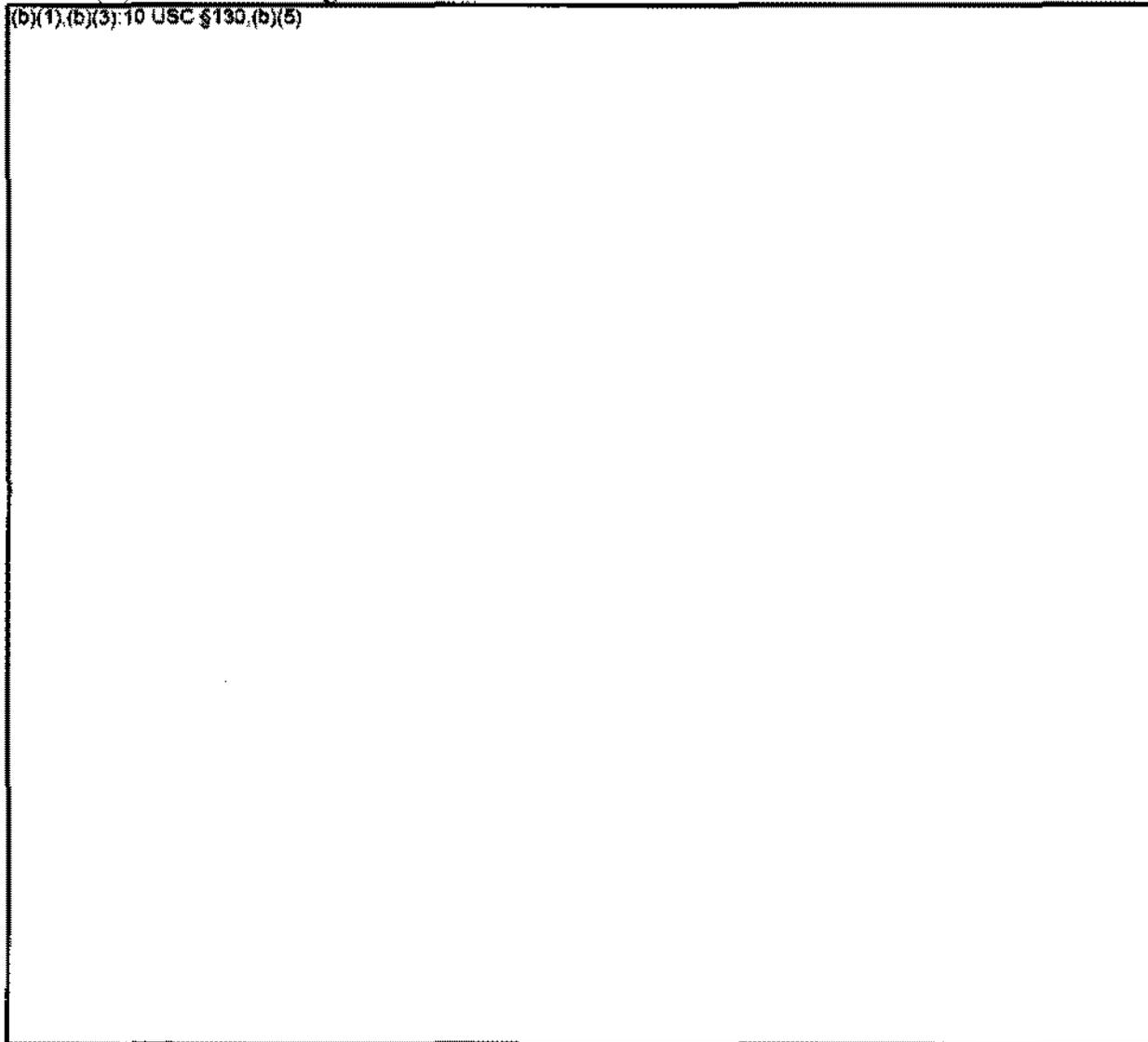
(b)(3); 10 USC §130, (b)(5) Regardless of any contribution to the failure, this kind of phenomena crossing multiple components is always difficult to capture in a Fault Tree. A Fishbone is ideal for enabling and capturing constantly changing hypothetical failure mechanisms and was

therefore created to aid the FTG-06a failure investigation. The most current instantiation is included in Appendix G.

1.2.4.2. ~~(U)~~ Fishbone and FRB Terminology

~~(U)~~ The program has terminology already in use regarding IMU to EO Sensor errors and divert thruster rough combustion. The FRB usage of such terms is somewhat different within this report and explained below.

1. ~~(U)~~ Attitude Pointing Errors



~~(U)~~ The current Fishbone is broken into three pieces to aid in managing and using the Fishbone. They are connected generally as follows (see Figure I-6):

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- (U) To aid in keeping track of ideas in the Fishbone, it has a red track highlighting any current leading hypothesis and a blue track for secondary hypothesis or effects, all suggested by the best data currently in hand.
- (U) The Fishbone has been used primarily to aid in thinking through the investigation and ensuring Fault Tree boxes take all pertinent hypotheses and ideas into account. But the Fishbone is not used as a formal traceability or closure tool. The FRB findings of root cause are mapped to the fishbone located in paragraph 9.4.

1.2.5. (U) Data Management

- (U) All data generated during the test event, as well as all data produced and presented during the course of this FTG-06a failure investigation was archived with the MDA/DTX Missile Defense Data Center's (MDDC) Data Center Program (DCP). The DCP's mission is to archive and preserve Ballistic Missile Defense data and provide controlled access and data distribution to the MDA enterprise, as required. The DCP is responsible for the archival, management and distribution of all MDA Mission-Related Scientific and Technical (MRST) data. MDA Directive 3200.06, dated 13 June 2008, specifies that all MDA data must be archived at the data center and includes data resulting from tests, evaluations, supporting missile defense experiments, demonstrations, data analyses, and other efforts funded or sponsored by MDA that collect, manage, produce, analyze, manipulate or promulgate MRST data.
- (U) The FTG-06a Data Catalog was established to accurately validate the data collected for the FTG-06a test event, and ensure that all collected data, from all possible data sources, was available to and controlled by the FRB. This data cataloging included all pre-coordinated data exchanges, as defined in the Integrated Data Management Plan, as well as other data sources and information from internal collection log files, Associated Operations, and external sources not normally captured by the MDDC.
- (U) Additionally, all of the data received, developed, and utilized during the FRB investigations are archived at the MDDC. The data products archival at the MDDC is structured the same as this final report, with the FRB Final Report and each appendix as a separate and unique data item. Users interested in obtaining access to the FTG-06a FRB data will be required to register with the DCP. The registration process provides validation and verification of the user's requirement to request and access BMDS test data.

SECTION 2. (U) FINDINGS OF FACT

2.1. (U) TEST RECONSTRUCTION

- (U) All pre-launch activities were conducted in accordance with the nominal countdown timeline. The EKV Payload passed all pre-launch health checks, including all Built-In-Tests (BIT), an IMU health and status check, all Signal Conditioning Unit/Laser Initiation System BIT checks, and an evaluation of the EKV Payload Launch Commit Criteria. All parameters associated with this health check were nominal and the EKV was declared ready for flight.
- (U) Figure 2-1 outlines the timeline associated with FTG-06a sequence of key events. The following text outlines these events in detail.

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(b)(1) (b)(3) 10 USC §130 (b)(5)

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(b)(1)-(b)(3) to USC §130.(b)(5)

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(b)(1), (b)(3), 10 USC §130, (b)(5)

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(b)(1), (b)(3), 10 USC §130, (b)(5)

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(b)(1), (b)(3) 10 USC §130 (b)(5)

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(b)(1), (b)(3); 10 USC §130 (b)(5)

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(b)(1), (b)(5), 10 USC §130, (b)(5)

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(b)(1) (b)(3) 10 USC §130 (b)(5)

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(b)(1), (b)(3), 10 USC § 130, (b)(5)

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(b)(1), (b)(3), 10 USC §130, (b)(5)

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(b)(1), (b)(3), 10 USC §130, (b)(5)

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(b)(1), (b)(3), 10 USC §130, (b)(5)

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(b)(1), (b)(3), 10 USC §130 (b)(5)
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(b)(1), (b)(3); 10 USC §130 (b)(5)

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(b)(1), (b)(3), 10 USC §139, (b)(5)

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(b)(1),(b)(3) 10 USC §130 (b)(5)

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(b)(1),(b)(3); 10 USC §130.(b)(5)

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(b)(1),(b)(3), 10 USC §130,(b)(5)

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(b)(1);(b)(3); 10 USC §130.(b)(5)

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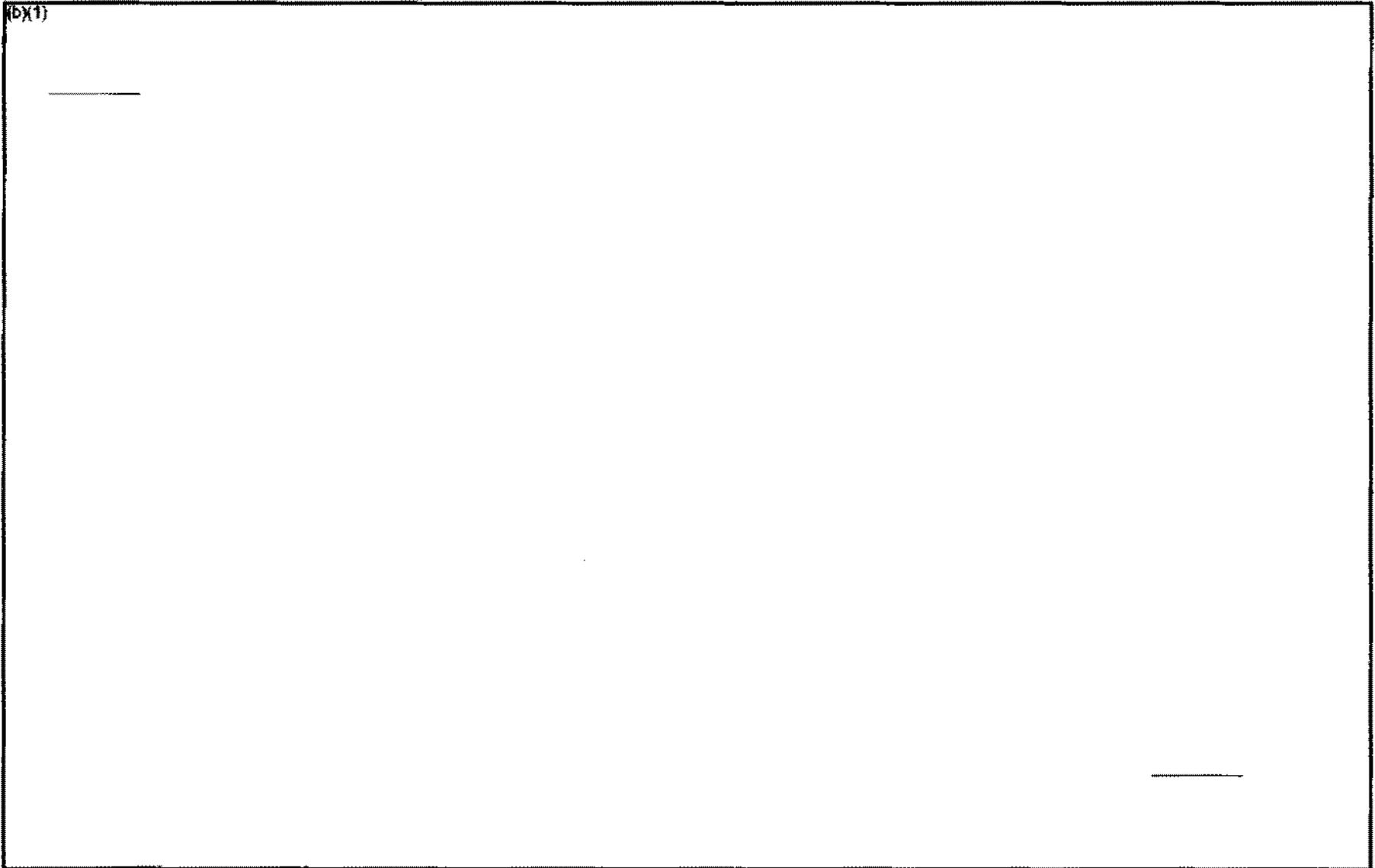
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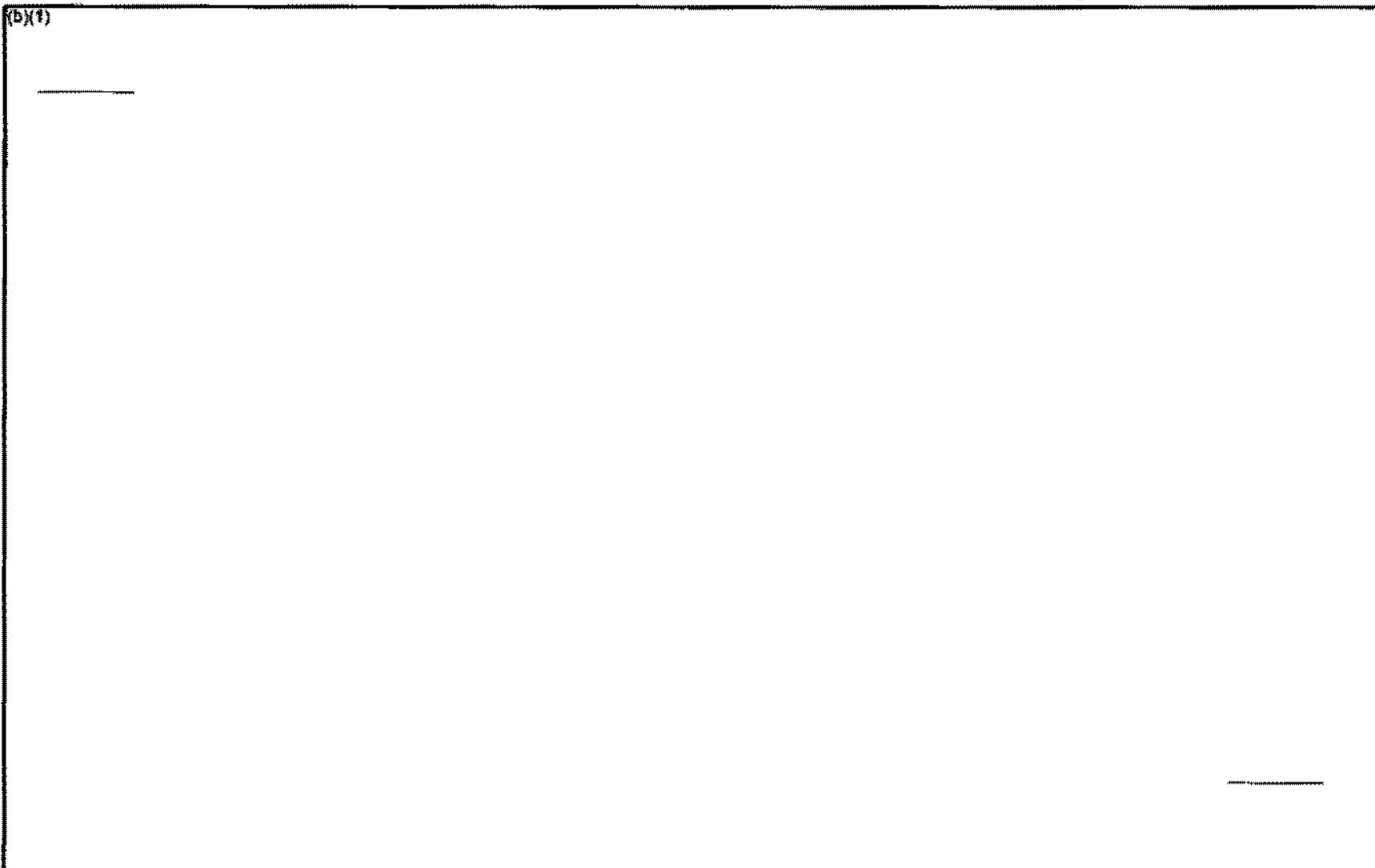
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(b)(1)



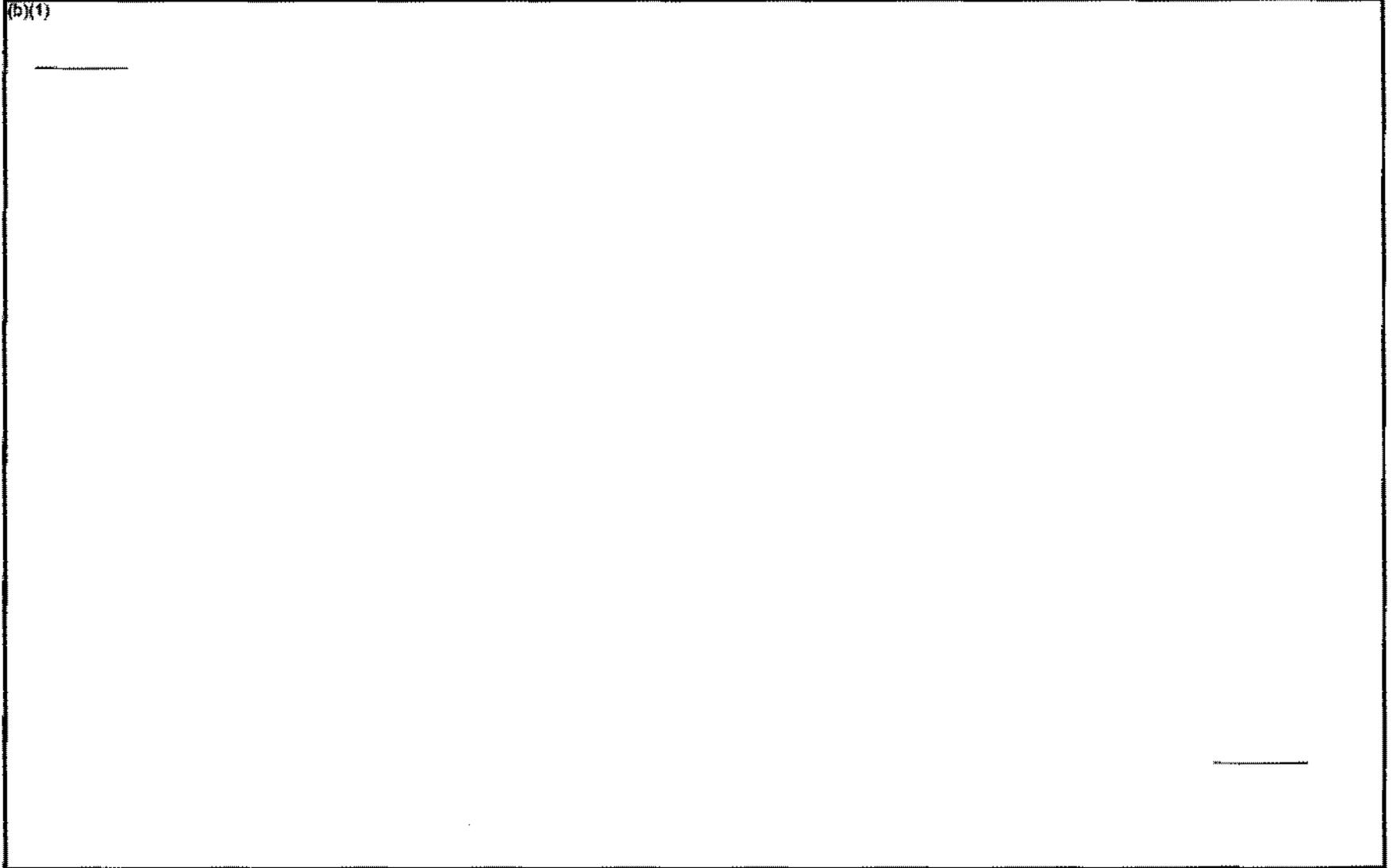
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(b)(1)



FTG-06a Fault Tree (3 of 11) ~~(U)~~

(b)(1)



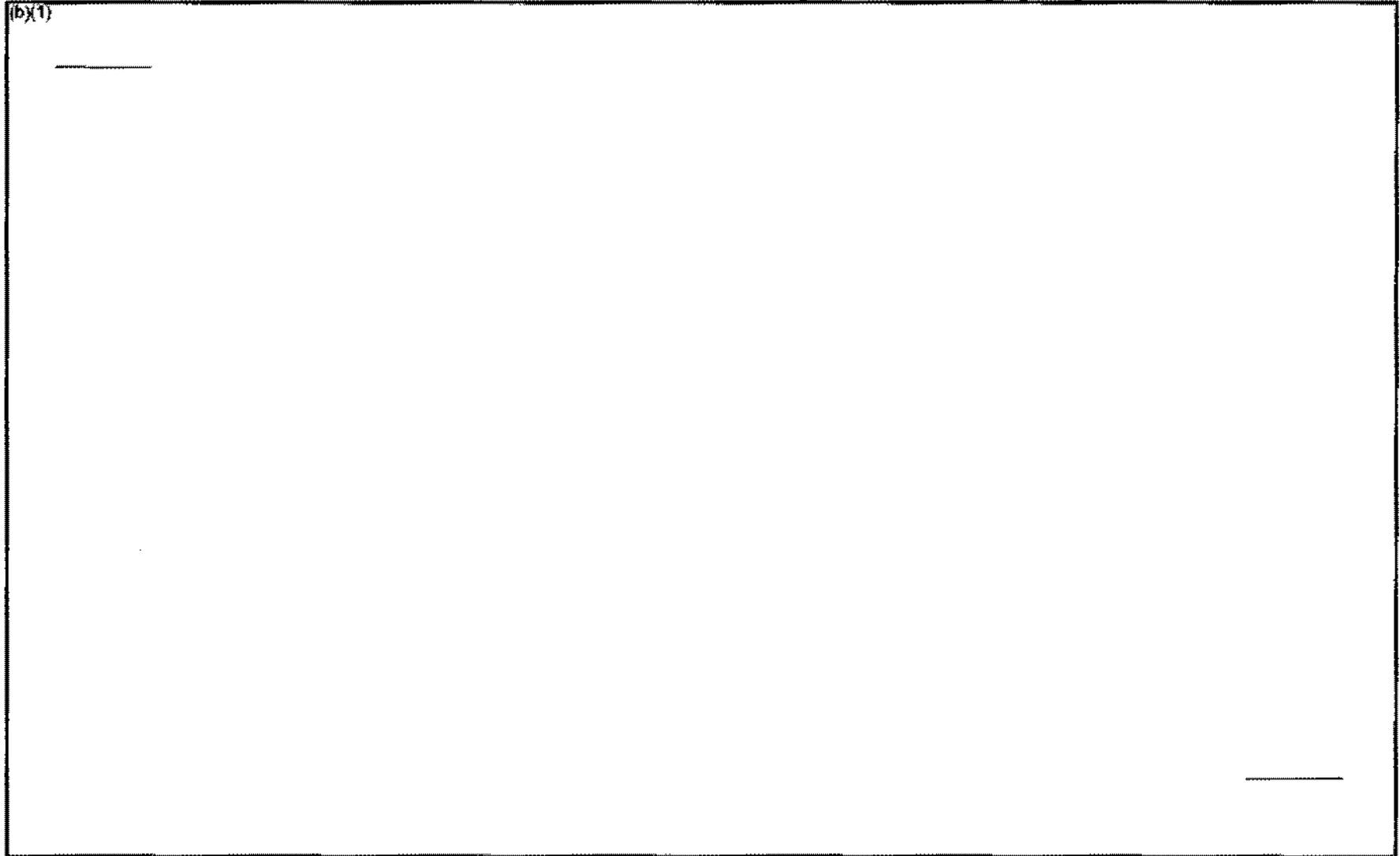
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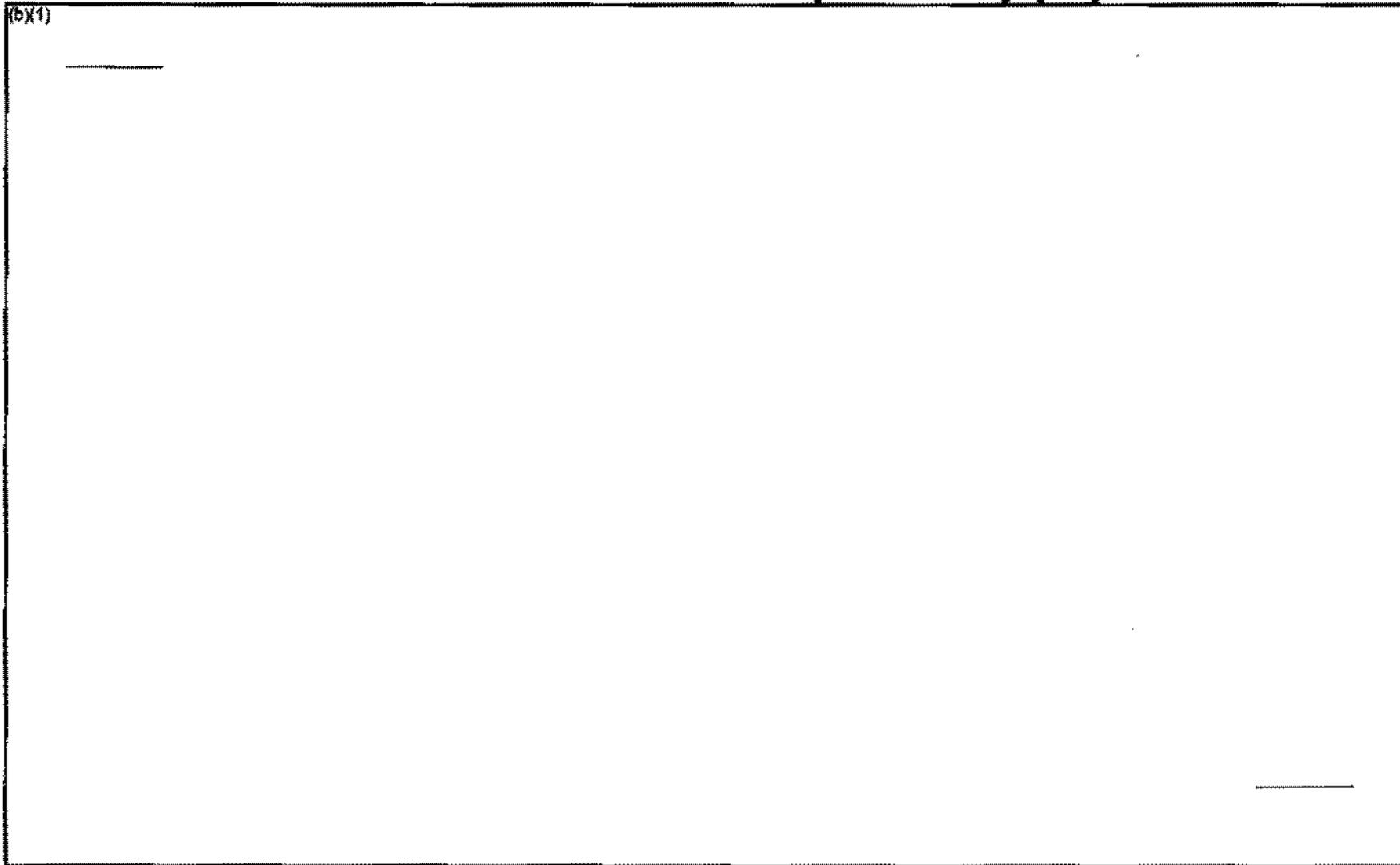
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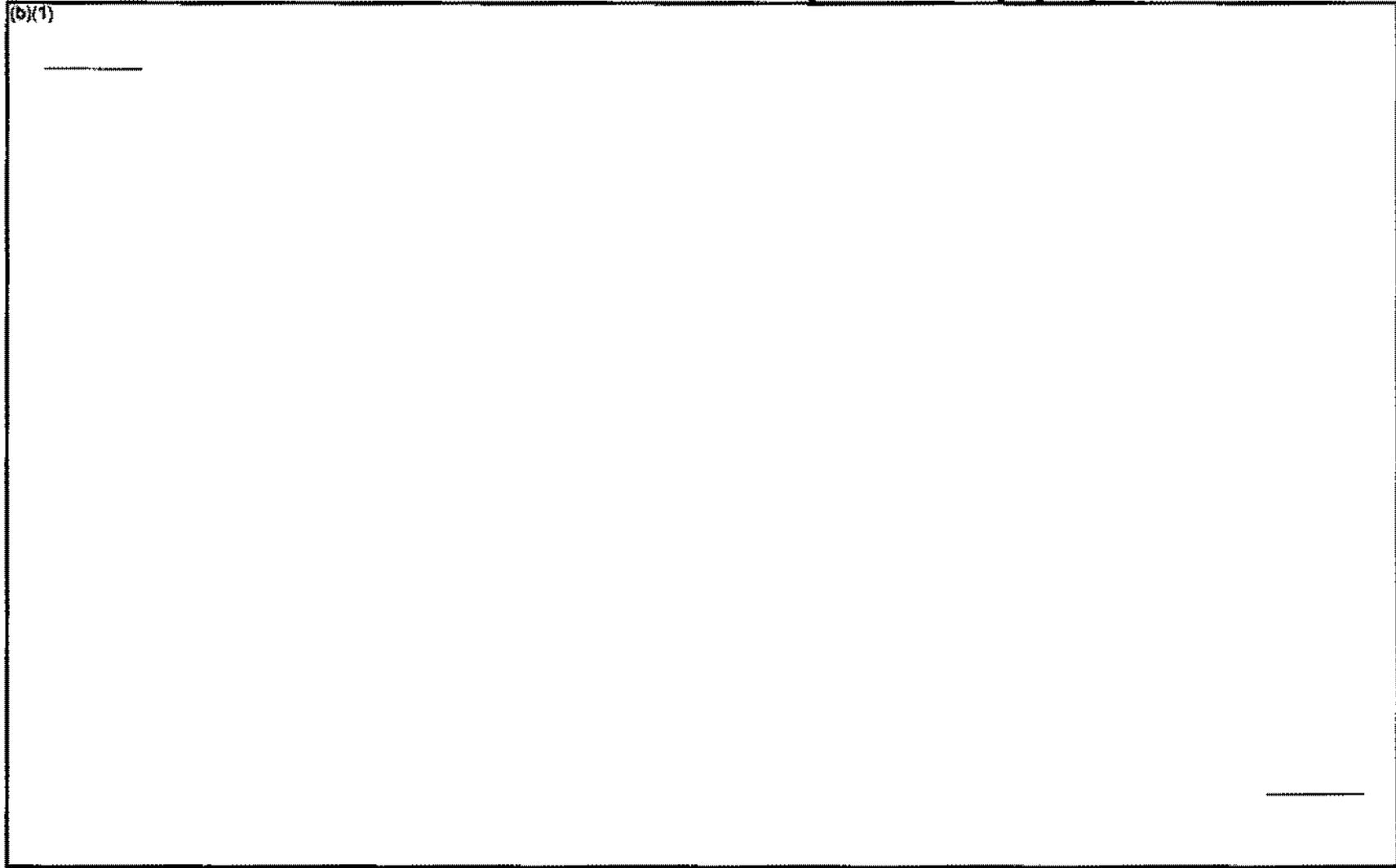
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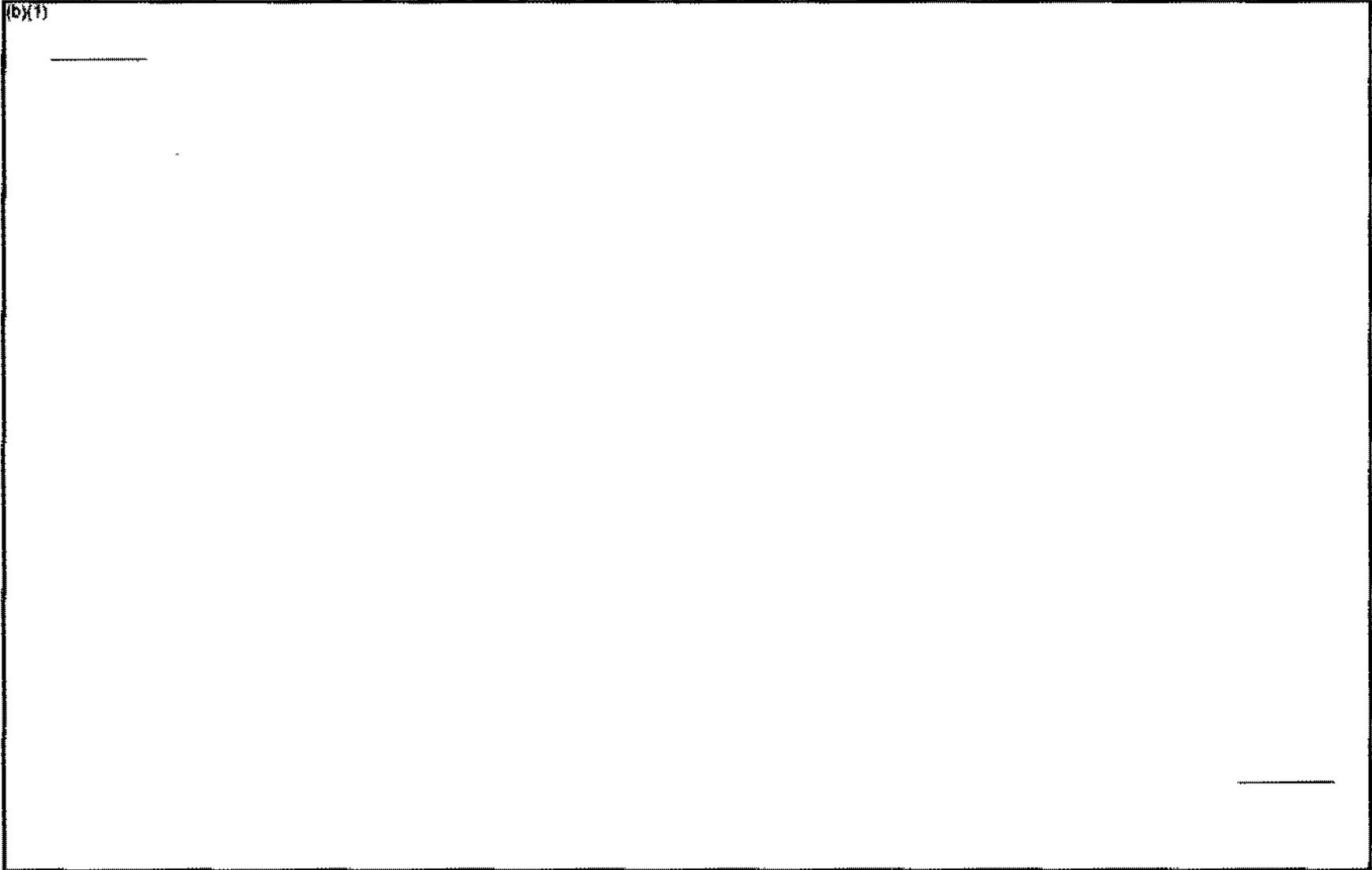
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(b)(1)



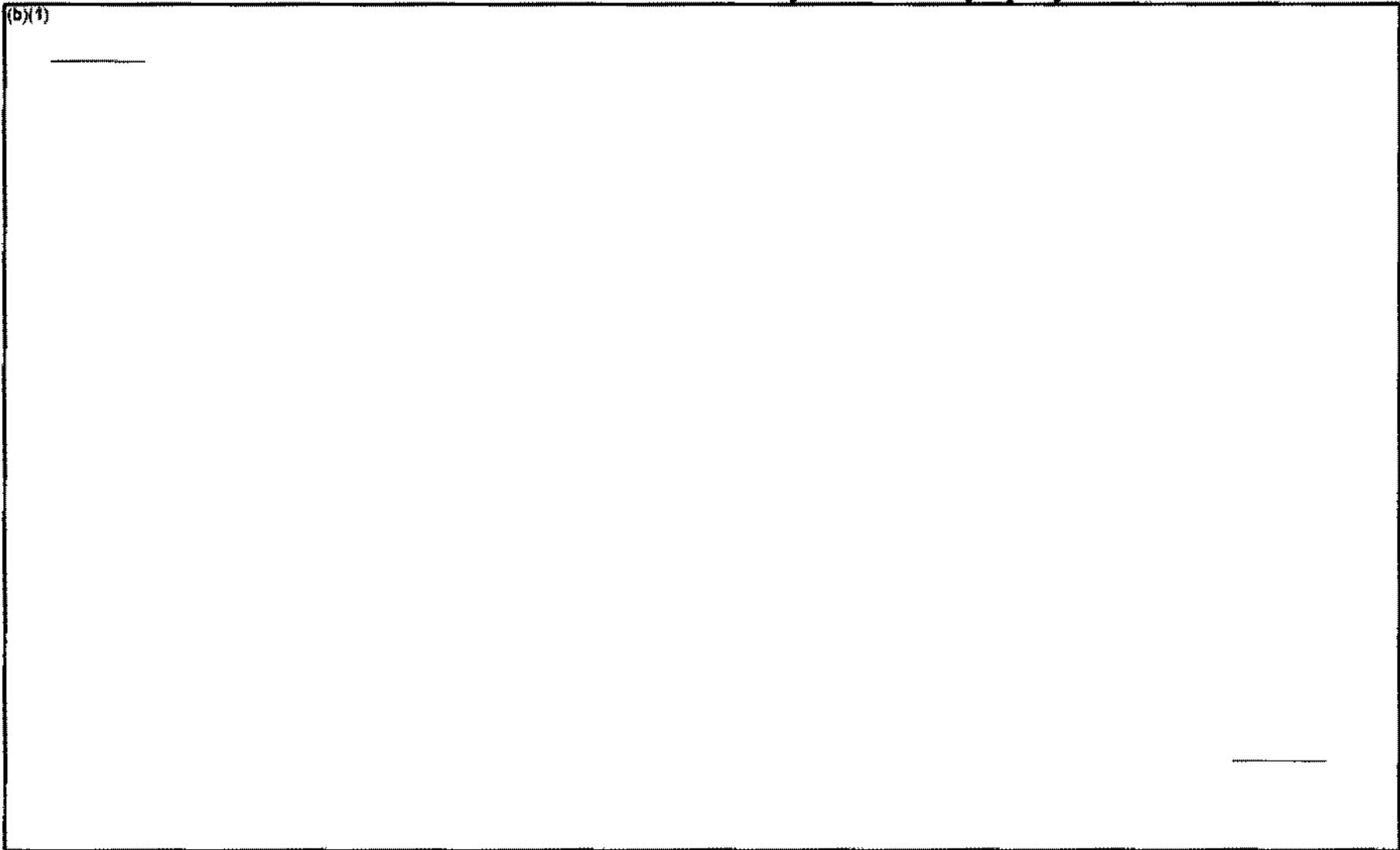
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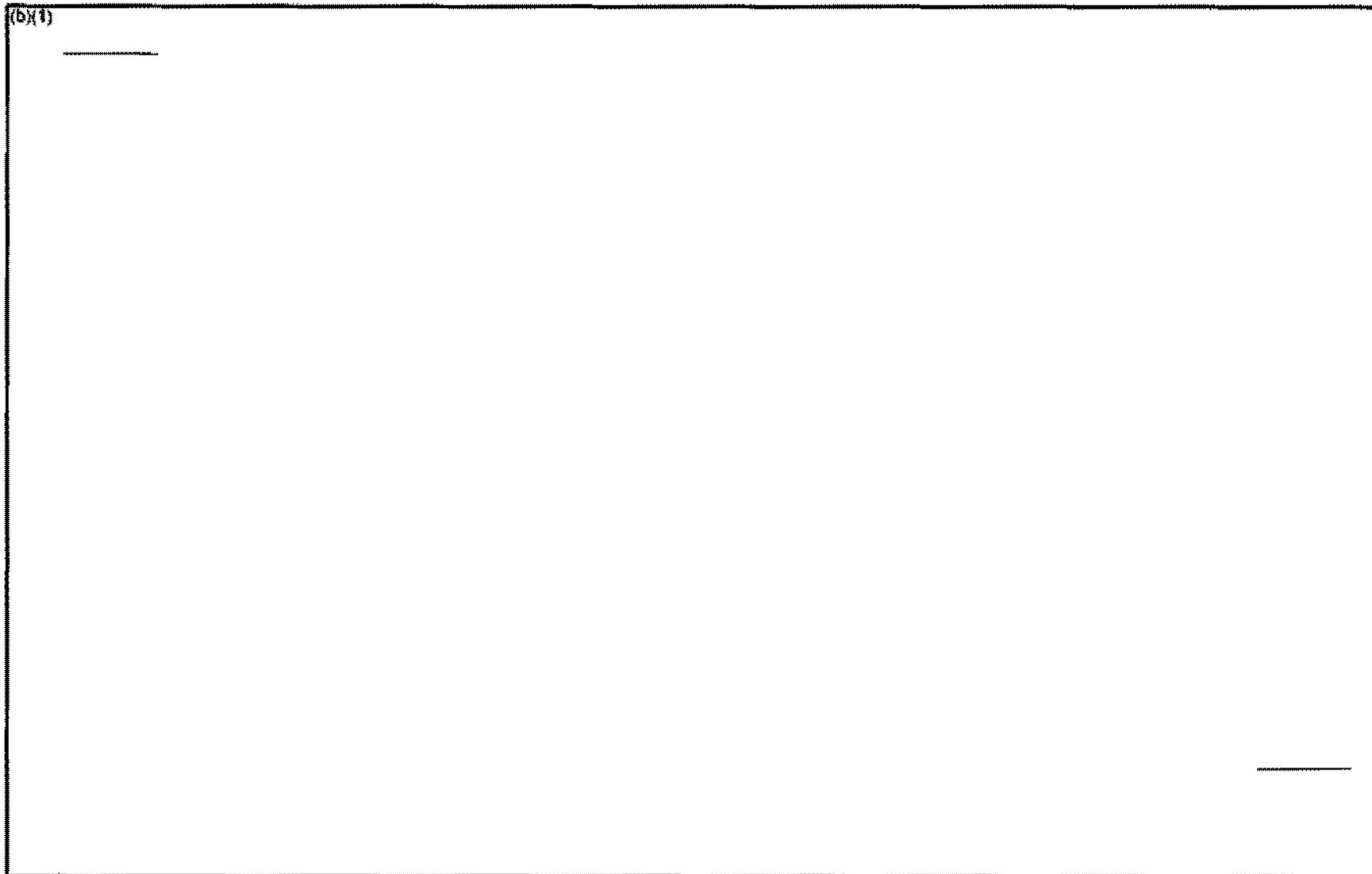
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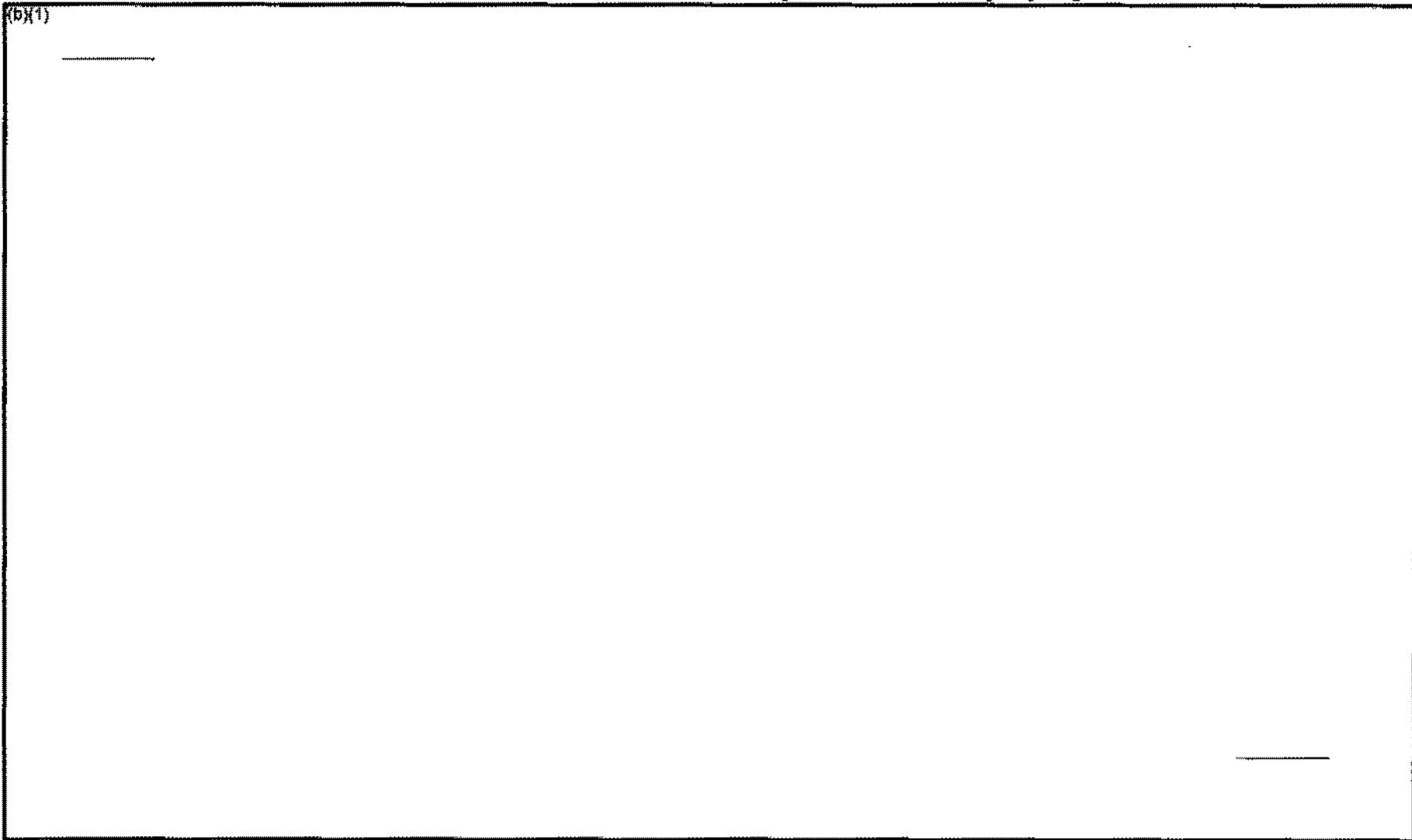
FTG-06a Fault Tree (10 of 11) (U)

(b)(1)



FTG-06a Fault Tree (11 of 11) (U)

(b)(1)



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(b)(1), (b)(3) 16 USC § 150, (b)(5)

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(b)(1), (b)(3), 16 USC § 130, (b)(5)

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(b)(1)

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(b)(1), (b)(3); 10 USC 5130 (b)(5)

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(b)(1),(b)(3); 10 USC §130 (b)(5)

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(b)(1),(b)(3), 10 USC §130,(b)(5)

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(b)(1), (b)(3), 10 USC §130, (b)(5)

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SECTION II. (U) APPENDICIES

- (U) Appendix A Acronyms
- (U) Appendix B Pre-Test Mission Documentation
- (U) Appendix C Post-Test Mission Documentation
- (U) Appendix D FRB Team Processes and Approvals
- (U) Appendix E Test Objectives Memorandum
- (U) Appendix F Fault Tree
- (U) Appendix G Fishbone
- (U) Appendix H FTICRs
- (U) Appendix I Testing Documents
- (U) Appendix J FRB Status Briefings
- (U) Appendix K Briefings Provided to FRB
- (U) Appendix L Other FRB Files
- (U) Appendix M FTG-06a Fault Error Tree