



U.S. FOOD & DRUG
ADMINISTRATION

Center for Biologics Evaluation and Research
Office of Blood Research and Review
Division of Emerging and Transfusion Transmitted Diseases
Product Review Branch

FINAL REVIEW MEMORANDUM

Date Received: May 12, 2015
June 12, 2015
December 14, 2016
March 23, 2017
May 18, 2017
May 23, 2017
October 10, 2017
November 20, 2017

Reviewer: Lisa Simone, Ph.D., PRB/ DETTD

Through: David A. Leiby, Ph.D., Chief, PRB/DETTD

To: Babita Mahajan, Ph.D., Scientific Lead, PRB/DETTD
RPM: Iliana Valencia, RPM, RPMS/OBRR

Product: *Babesia microti* Nucleic Acid Test (NAT)
Sponsor/Applicant: Oxford Immunotec, Inc. (was: IMUGEN)
Submission Type: Biologics License Application
STN: 125588/0
Scientific Disciplines Reviewed: Software and Instrumentation

Recommendation: Approvable.

Note to Lead Reviewer/Scientific Lead: A final comment should be sent to the applicant as described in Reviewer Notes and Recommendations, Section 5d) Reviewer Recommendation.

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1 Purpose, Intended Use and Regulatory History

Purpose

The applicant submitted two biologic license applications (BLAs) for the screening of blood donors for evidence of *B. microti*. These include:

- *Babesia microti* NAT (nucleic acid test by real time polymerase chain reaction) (this submission, BL125588)
- *Babesia microti* AFIA (indirect fluorescent antibody) (BL 125589)

The same software is common for these two BLAs, although some software functionality is unique to the NAT Intended Use. As a result, there is significant overlap in the review of these two submissions, which were reviewed concurrently.

Intended use / Indications for use

The *Babesia microti* NAT is a nucleic acid screening assay for the detection of *B. microti* DNA in human whole blood samples (with EDTA as anti-coagulant). This test is intended for use as a donor screening test to detect *B. microti* DNA in whole blood samples from individual human donors, including volunteer donors of whole blood and blood components, as well as other living donors. It is also intended for use as to screen organ and tissue donors when specimens are obtained while the donor's heart is still beating.

This test is not intended for use on specimens from cadaveric (non-heart beating) donors.

The test is not intended for use on samples of cord blood.

This test is not intended for a use as an aid in the diagnosis of *B. microti* infection.

Past and Concurrent Submissions

- IND 14532 (and its related amendments) submitted for clinical studies to support the Babesia NAT and AFIA assays – received 02/21/2012
- BL 125589 *Babesia microti* Arrayed Fluorescence Immunoassay (AFIA) – received 05/12/2015
- BQ 170068: Submission Issue Meeting July 6, 2017 for inspectional issues and software
- BQ 170083: Submission Issue Meeting Request August 4, 2017 for software issues

Interactions for current submission (communication history)

- 05/12/15: Original submission received
- 06/12/17: Amendment 1: Summary information for original submission

- 09/29/15: CR letter issued, including for original, generic software deficiencies rather than actual software deficiencies
- 02/10/16: Face to Face, including question about software deficiencies
- 12/14/16: Amendment 13: Resubmission received with CR issue responses
- 02/17/17: IR email sent, with relevant 9/29/15 software questions not sent in original CR and new issues resulting from CR responses
- 03/23/17: Amendment 15: IR response received for 02/17/17 issues
- 04/14/17: IR email sent for software issues from 03/23/17 response
- 04/20/17: Telecon for software and cybersecurity issues
- 05/18/17: Amendments 23, 24: Risk documentation to more closely align with ISO 14971
- 05/18/17: Emailed advice in response to risk documentation provided 5/18/17
- 05/23/17: Amendment 25: Status update on software with documentation
- 06/16/17: CR letter issued, inspectional issues and major software issues
- 07/17/17: Submission Issue Meeting Request for feedback on software; FDA written response sent 08/04/17. Meeting request cancelled by the applicant on receipt of FDA responses.
- 10/10/17: Amendment 32: Complete Response received
- 11/09/17: IR email sent for software
- 11/20/17: Amendment 34: IR response received

2 Final Review Summary for Software and Instrumentation

*The following is a **final** review summary for software and instrumentation in original submissions and significant supplements that can be cut-and-pasted into final documentation such as SBRAs/SSDs.*

The following is a summary overview of software, instrumentation and risk management information provided to support a reasonable assurance that the device is safe and effective for its intended uses and conditions of use.

Versioning: Software: (b) (4) Build 1.0.5.5 (not for commercial release). Hardware: (b) (4) workstations in client/server configuration for processing, PCR testing, and reporting; all running supported versions of Windows (Windows (b) (4) and Windows Server (b) (4)). During the review period, the software was upgraded from Build 1.0.5.4 to correct an unresolved anomaly and to migrate a database server from an unsupported version of Windows.

Device Description: The system supporting the NAT and AFIA assays is comprised of an RNA/DNA extraction system, real time PCR system, custom (b) (4) software, refrigerator, freezer and other sample handling tools. Custom software called (b) (4) is used to collect and report data for blood donor sample testing within the Oxford facility. It does not control laboratory equipment, but facilitates collection of data, stores

batch and sample data and test results where the data is acquired through barcode scanning, touch-screen and keyboard entry, and electronic file import. Sample results are electronically transmitted via email or FTP to the submitting entity.

Risk Management: Risk processes and associated artifacts were significantly updated and refined for better alignment with ISO 14971 “Medical devices – application of risk management to medical devices” and harmonized between the NAT and AFIA assays and submissions. Use of the new process allowed the applicant to capture significantly more risks and mitigations at a level of detail appropriate to ensure that proposed risk control measures could be appropriately verified. Reanalysis of risk across the system led to several new and changed requirements and specifications, and the development of corresponding testing.

The initial hazard analysis included 12 incompletely-developed risks. The final risk assessment included 2 Excel spreadsheets with a total of 185 risks fully characterized with explicit hazards, relevance to the software or product, cause, sequence of events, outcome, hazardous situation, premitigation and postmitigation assessment of risk, controls measures, and the type of mitigation employed to reduce the risks to acceptable levels. The two risk documents address (b) (4) manufacturing and assay risks, and cybersecurity risks.

Risk analysis revealed 21 manufacturing and assay risks and 43 cybersecurity risks with a premitigation assessment of “Not Acceptable” related to alteration or deletion of stored data (including results), and reporting incorrect negative results. These are caused by issues with system access, performance, results reporting, interface and audit functionality. Primary hazardous situations include: 1) release of an infected unit for use in transfusion, 2) a unit inappropriately discarded, and 3) a unit delayed prior to transfusion or discarded, reducing the donor blood pool. All risks have been reduced “as far as possible” through multiple mitigations, and the applicant has provided a further Risk/Benefit analysis to support that the overall residual risks are acceptable. Overall, the applicant has done an impressive job establishing processes which should allow them to ensure that existing risks remain controlled, and that new risks can be easily assessed and mitigated.

Unresolved Anomalies: One unresolved anomaly related to incorrect highlighting of Ct values and possible false negative results was corrected during the course of this review, leaving no unresolved anomalies.

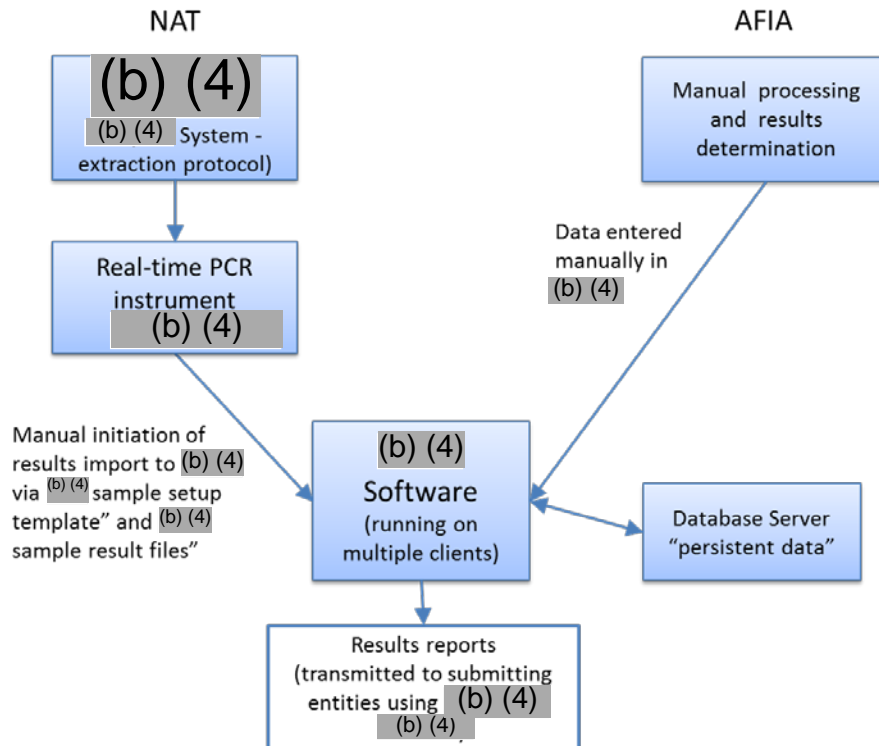
Testing: Verification and validation testing initially focused on Installation Qualification (IQ), Performance Qualification (PQ), and Operational Qualification (OQ) testing of the (b) (4) software. Because this black box testing cannot exercise all pathways through software and did not include verification of the many new risk mitigations, additional unit and integration testing was developed and performed. This focused on higher level risks associated with errors and unexpected conditions related to user inputs and workflow, file import errors from the (b) (4) instrument, database integrity and performance, and cybersecurity mitigations related to data loss or corruption, improper access and improper software patching. All new testing was successfully completed.

Development Management: The software development activities included establishing detailed software requirements, linking requirements with associate verification tests, verification and validation testing, defect tracking, configuration management and maintenance activities to ensure the software conforms to user needs and intended uses.

3 Device Description Overview

The system supporting the NAT and AFIA assays is comprised of an RNA/DNA extraction system, real time PCR system, custom (b) (4) software, refrigerator, freezer and other sample handling tools. Custom software called the (b) (4) is used to collect and report data for blood donor sample testing within the Oxford facility.

The following figure illustrates the relationship between the NAT and AFIA assay processing paths and the combined role that the (b) (4) software plays. Both the NAT and AFIA assays require a number of manual operations before data is inputted into the (b) (4) software. The AFIA processing is completely manual. As a result, the “device” under review is actually a combination of the manual and automated processing, and the use of the (b) (4) software to manage the processes.



The (b) (4) software does not control laboratory equipment, but facilitates collection of data, stores batch and sample data and test results where the data is acquired through barcode scanning, touch-screen and keyboard entry, and electronic file import. Sample results are electronically transmitted via email or FTP to the submitting entity.

The software has four primary functional roles and two secondary functional roles. These are listed and described below:

Primary Functional Roles:

1. Process: provides data entry screens to create new batches, add samples to a batch, review and close batches and print barcode labels.
2. IFA: provides data entry screens to create IFA test runs, add slide(s) to a test run, add sample(s) to a slide, and to enter IFA test results for each sample.
3. PCR: provides a screen to import (b) (4) sample template setup, and (b) (4) sample result files.
4. Report: provides screen(s) to create two types of reports: Proof Copy and Final sample results.

Secondary Functional Roles: (Note: these are not required to perform essential services for data collection and reporting, and are restricted to users with elevated privileges):

1. Audit: provides read-only access to data for a specific sample.
2. Admin: provides limited data management functionality.

Additional information about the system equipment and device infrastructure can be found in Appendix 2: Device Description Details.

4 Review: Original Submission and Significant Supplements

Scope

All documentation related to software and instrumentation was reviewed. See section 5, “Software and Instrumentation Documentation Status and Adequacy” for specific documents reviewed.

Review

Table 1 below reflects the final status of the review with respect to specific documentation outlined in Agency’s software guidance document (Guidance for the Content of Premarket Submissions for Software Contained in Medical Devices, available at <http://www.fda.gov/RegulatoryInformation/Guidances/ucm089543.htm>). Please see section 5, “Software and Instrumentation Documentation Status and Adequacy” for a detailed review of each type of documentation.

Table 1. Summary of Software Documentation

	Present	Missing	Adequate (Yes/No/ Assessment Incomplete)
1. Level of Concern:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
2. Software Description:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
3. Device Hazard Analysis:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
4. Software Requirements Specifications:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
5. Architecture Design Chart:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
6. Software Design Specifications:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
7. Traceability Analysis/Matrix:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
8. Software Development Environment:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
9. Verification & Validation Testing:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
10. Revision Level History:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
11. Unresolved anomalies:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
12. Cybersecurity:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Yes
	YES	NO	
EMC Review Required?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

Due to the depth of the interactive discussions, please also refer to the Interactive Questions in Appendix 1: Sponsor/Applicant Interactions and Communications for the detailed issues and resolutions.

Versioning: During the course of this review, the applicant was requested to correct an unresolved anomaly and update the software version from Build 1.0.5.4 to Build 1.0.5.5. Updated design control documentation was provided to support the upgrade. See Interactive Questions #6 and 9. This was coupled with migration of a database server from an unsupported version of Windows, as discussed in Interactive Question #10.

Requirements, Architecture and Specifications, Traceability Matrix: Initial design control documents were extremely limited in detail. Final documentation is much more comprehensive, and allows traceability between design inputs and design outputs and reference to risk documentation. The requirements are significantly expanded to more adequately reflect the known requirements of the system, and the architecture document more clearly includes the components of the system and boundaries with the business IT infrastructure and outside world. Performance requirements for the (b) (4) software, hardware, and IT infrastructure were alternately included and removed, and finally restored and optimized after the applicant came to understand that the infrastructure performance is associated with identified risks.

Specifications were initially sparse and untestable but upgraded to include significant detail for the individual process workflows and screenshots depicting user interactions and error checking functionality. The specifications are not traditional statements with testable metrics because the specifications were reverse-engineered after the (b) (4) software was written. This is adequate for this submission, although the applicant may be challenged to add future specifications without significant changes to the document. The (b) (4) database server was upgraded at FDA's request from an unsupported version of Windows (Windows Server (b) (4) to Windows (b) (4)). See Interactive Questions #2, 8, 9, 11 and 12 (requirements), #2, 3 and 13 (architecture) and #4 (specifications). The updated traceability matrix appropriately links requirements, specifications, risk IDs and corresponding test cases. See Interactive Questions #1 and 5.

Hazard analysis and risk management: The applicant originally had no risk management process. Documentation for the original submission was developed as part of a "retrospective design review." Although some initial documentation referenced FDA's guidance, "Q9 Quality Risk Management," the applicant ultimately designed a risk management process and associated documentation to harmonize the NAT and AFIA risk assessments and to better align with ISO 14971 "Medical devices – application of risk management to medical devices" rather than with ICH Q9. This is acceptable.

The initial hazard analysis included 12 incompletely-developed risks. The final risk documentation contained two spreadsheets of risk information. Final (b) (4) manufacturing and assay risk assessment included an Excel spreadsheet with 125 risks with explicit hazards, relevance to the software, relevant component, cause, outcome, hazardous situation, premitigation and postmitigation assessment of risk, controls measures, and type of mitigation. A separate spreadsheet included 60 cybersecurity related risks. Primary risks result from assay failure, false negative results, false positive results, and cybersecurity hazards which have the possibility of allowing any of the above. These were associated with unauthorized access to various parts of the system, source code or database that might allow loss or corruption of data, improperly patched software or firewalls or infected files, add-ons and logins. Primary hazardous situations include release of an infected unit for use in transfusion, a unit inappropriately discarded, and a unit delayed prior to transfusion or discarded, reducing donor blood pool.

Risk analysis revealed 21 manufacturing and assay risks and 43 cybersecurity risks that were considered "Not Acceptable" prior to mitigation. These were associated with unauthorized access to various parts of the system, source code or database that might allow loss or corruption of data, improperly patched software or firewalls or infected files, add-ons and logins. Other "Not Acceptable" risks were associated with alteration of data caused by inappropriate access to the system, operator error, incorrect information sent to the customer, sample ID tracking and data traceability issues. All risks were reduced to at least "As Far As Possible."

The final risk assessment is significantly more comprehensive than in the original submission, with multiple causes for the same risks individually captured and assessed. The assessments

appear to capture the risks and mitigations in the system, and are of an appropriate level of detail to ensure risk control measures can be appropriately verified.

The significant improvement in the applicant's final risk documentation was possible because the risk management procedure was completely redesigned to align with ISO 14971 "Medical devices – application of risk management to medical devices." A detailed procedure for risk analysis was provided, including how information is added to the risk tables. Both (b) (4) methods have been added for consideration in the early stages of product design. Risk processes are integrated into the larger quality system, and the relationship to premarket and postmarket activities is outlined. The specifics of the improved process are discussed in Section 5 for "Device Hazard Analysis."

Overall, the applicant has done an impressive job establishing processes which should allow them to ensure that existing risks remain controlled, and that new risks can be easily assessed and mitigated. See Interactive Questions #1, 7, 10 and 11 related to risk management.

Verification and validation testing: The applicant supplemented originally-performed Installation Qualification (IQ), Performance Qualification (PQ), and Operational Qualification (OQ) testing with some additional unit, integration and system testing as outlined in FDA's premarket guidance document. However, because the specifications were developed by reverse engineering the software, they were not constructed in a manner to facilitate true verification testing such as unit level testing. See Interactive Question #5.

At this point, it appears that the benefits of getting this test to market outweigh the risks of forcing the applicant to undergo the lengthy process of fully reverse engineering the design specifications and testing schemes to ensure verification has been performed completely. Instead, focus was placed on developing an adequate risk process and using that to guide the review to ensure testing would adequately cover the identified risks. The applicant developed additional testing for error conditions and unexpected conditions related to user inputs and file imports from the (b) (4) instrument (see Interactive Questions #10 and 12), testing for database integrity and performance (see Interactive Question #2), and testing of cybersecurity mitigations for unacceptable risks (see Interactive Question #13). The original five test documents were supplemented with an additional 14 testing documents.

Cybersecurity: The initial submission contained no references to cybersecurity, despite the software running on several individual computers and servers that are shared with the applicant's business IT infrastructure. The IT business network is not completely isolated from the computers used to perform the assays, which exposes the (b) (4) software and servers to additional cybersecurity risks. To address this, a new cybersecurity risk assessment was performed and cybersecurity testing protocols developed and completed. The applicant developed new processes to ensure several common mitigations for cybersecurity hazards have been implemented. A new "Business Continuity and Disaster Recovery Plan" was created and the "Information Technology Security Policy" was significantly updated. See Interactive Questions #5, 7 and 13.

1. Level of Concern (LOC): Acceptable

In the original submission, in the Level of Concern document (062_Attachment 4-5-2 Imugen (b) (4) Level of Concern Determination.pdf) the applicant stated that the Level of Concern is Major. This is acceptable.

2. Software /Firmware Description: Acceptable

In the original submission, in the document (b) (4) Software Description” (063 Attachment 4-5-3 Imugen (b) (4) software description.pdf) the applicant stated that the (b) (4) is designed to collect and report data for blood donor sample testing within the Oxford (was: Imugen) facility. (b) (4) is designed to be a simple data collection and reporting tool and, as such, does not control laboratory instruments. (b) (4) also does not perform any algorithmic computation of instrument data to produce results.

The applicant further stated that (b) (4) is a client/server application that provides graphical user interface screens for laboratory technicians to process batches of samples sent by submitting entities to Oxford. The software is used to collect and store batch and sample data and test result data for the samples under test. Data entry is accomplished by barcode scanning, touch-screen and keyboard entry, and electronic file import. When testing and data collection is complete, laboratory managers use the software to produce reports of sample results which are electronically transmitted to the submitting entity. Data is persisted until testing is complete and a final sample report is produced. The reports associated with samples are reported back to the submitting entity.

The software has four primary functional roles and two secondary functional roles. These are listed and described below:

Primary Functional Roles:

1. Process: provides data entry screens to create new batches, add samples to a batch, review and close batches and print barcode labels.
2. IFA: provides data entry screens to create IFA test runs, add slide(s) to a test run, add sample(s) to a slide, and to enter IFA test results for each sample.
3. PCR: provides a screen to import the sample template setup from the (b) (4) real-time PCR system, and (b) (4) sample result files.
4. Report: provides screen(s) to create two types of reports: Proof Copy and Final sample results.

Secondary Functional Roles: (Note: these are not required to perform essential services for data collection and reporting, and are restricted to users with elevated privileges):

1. Audit: provides read-only access to data for a specific sample.
2. Admin: provides limited data management functionality.

Other: Several deficiencies were related to unresolved anomalies, the final version of software to be used, and various features.

- One unresolved anomaly related to incorrect highlighting of Ct values that exceed the threshold was corrected and addressed in Interactive Question #6.
- In contrast to original documentation, the applicant confirmed the software will not be recompiled for commercial release, as discussed in Interactive Question #9.
- Transmission of results data between the laboratory and blood establishment facilities is discussed in Interactive Question #8.
- One server was running an unsupported version of Windows, which was upgraded and validated during the course of this review, as discussed in Interactive Question #13.

For additional information and details on these areas, see the appropriate subsections in the Section: Software and Instrumentation Documentation Status and Adequacy.

Labeling

Because this submission represents a service rather than a device that is marketed and sold, labeling requirements are reduced. Screenshots of error detection and recovery related to risk mitigations implemented in labeling were reviewed. No other aspect of labeling review was performed.

5 Software and Instrumentation Documentation Status and Adequacy

Documentation Reviewed

The applicant provided the following documentation, in an attempt to fulfill specific documentation outlined in Agency's software guidance document. The design control documentation was submitted three separate times:

- 1) In the original submission, in the Table of Contents (061_Attachment 4-5-1 (b) (4) Software Table of Contents.pdf) the applicant described the documentation submitted for software. See folder "VOL_004_VOL_004_Chemistry_Manufac."
- 2) In the amendment received December 14, 2016, the applicant provided updates for nearly all design documentation. Responses to software and instrumentation questions begin on page 60 of the response document (001_NAT response to AI_ p 1 to 297.pdf).
- 3) Finally, in the CR response received October 10, 2017, the applicant provided significantly updated documentation, and provided the (b) (4) Submissions Table (050_Attachment-13.3_(b) (4) submissions table.pdf) that lists all documents ever provided for this submission related to software and instrumentation, when each was provided, and which are obsolete. **This table should be used to ensure correct documents are referenced because a majority are obsolete.**

On page 543 of the Software Description document, the applicant listed the hardware requirements, programming language(s) used, and off-the-shelf software required for software development.

3. Device (including software) Hazard Analysis (HA): Acceptable

In the original submission, the applicant provided a hazard document (064 Attachment 4-5-4 (b) (4) Hazard Analysis.pdf) for the (b) (4) which lists 12 potential hazards with estimated severity, hazard mitigation and a severity estimation after mitigation. No potential causes are listed. Mitigations are of too high a level to ensure they can reduce risk to acceptable levels.

In the original submission, the applicant did not provide an enumerated description of the hazards (including clinical hazards) presented by this device, the causes and severity of the hazards, the method of control of the hazards and the testing done to verify the correct implementation of that method of control, and any residual hazards. Deficiencies were written for the Complete Response sent December 2015, which started several interactions where the applicant reassessed their entire risk management methodology and developed new processes. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Questions #1, 7, 10, and 11 for resolution of deficiencies related to hazard analysis and risk management.

Additional documentation was provided in the following, where the documentation was significantly updated.

- Complete Response received December 14, 2016
- Amendment received March 23, 2017
- Complete Response October 10, 2017

After the resolution of all deficiencies, the applicant implemented a redesigned and substantially improved risk management procedure, LAB-QA-62 (BL 125589, 005_Attachment-5.1_LAB-QA-62_DocDetails.pdf; see Interactive Question #8 in the AFIA memo) that is aligned with ISO 14971 “Medical devices – application of risk management to medical devices.” The procedure was “activated” on December 18, 2017 “for all products and services manufactured and operated by Oxford Immunotec, Inc.” A “Memo on Risk Management” (LAB-MEM-38) was initially provided during interactive review to describe the thinking before the final procedure was produced and finalized. The following improvements were made:

- Removed economic considerations from assessment of risk
- Risk-benefit analysis now required for all risks, not just Unacceptable or ALARP risks
- Clarification of process risk management, including additional mitigation review
- Added use of (b) (4) as appropriate, at the commencement of product design
- Added (b) (4) methods (b) (4) for use in early design stages
- Updated terminology to align with ISO 14971

- Patient harm added to assessments, rather than limiting the analysis to erroneous patient sample results
- Risk management file is now updated during all phases of the design and development process
- Detailed flowchart created to show pre and post market risk management processes (Figure 1, page 7)
- A detailed procedure for risk analysis is provided, including how the information is entered into the risk management table. Product risk assessment is based on an FMEA. For blood donor screening, a more detailed approach is required. Multiple risk controls are required to reduce the risk as low as possible; each risk control must be assessed and scored individually to assess residual risk. Risk acceptability is different for donor screening tests and IVDs intended to aid in diagnosis.
- Full integration of postmarket information into the risk processes
- Documentation storage requirements and mitigation review

Final risk documentation is included in the following documents:

- Cybersecurity: 046_Attachment-12.1_DOC-RSK-9_Cybersecurity Risk Assessment.xlsx
- (b) (4) software: 030_Attachment-6.10_IT-CSV-PDF-41 (b) (4) Risk Analysis Rev. 1.4.xlsx
- Risk Management Process: 001_Attachment-1_LAB-QA-62_DocDetails.pdf (from AFIA submission)
- Overall Risk/Benefit and Residual Risk Summary: 003_Attachment-3_Risk Benefit Analysis and Overall Residual Risk Summary.pdf (from AFIA submission)

During the course of this review, the applicant created a “Business Continuity and Disaster Recovery Plan” (Attachment_20.1-DOC-POL-1.pdf) that focuses on business risk and includes data backup and recovery plans. The applicant also provided a substantial update to the “Information Technology Security Policy” (Attachment_20.2-IT-SEC-POL-01&DocDetails.pdf) that includes policies for accounts management, password management, encryption, data security, and software patches and updated, including antivirus updates.

In summary, risk management is not easy, and there is no single accepted way to perform an adequate assessment. Some of the terminology and claims could be better implemented, although overall, the applicant appears to have identified the major hazards and implemented reasonable mitigations for the associated risks.

In the initial hazard analysis, each of 12 potential hazards was associated with a severity estimate, a hazard mitigation, and a severity estimate after mitigation. The applicant now recognizes that severity generally does not change with mitigation, and that risk is the combination of severity of harm, and probability of occurrence of harm. The final risk assessment is implemented in Excel with automatic calculations, and adds hazards associated with cybersecurity, manual operations, and software issues that could lead to incorrect results. The final risk tables include a wealth of columns for premitigation and postmitigation assessment

of risk, the relevance to software, countermeasures to take, mitigation type, and the assay to which the risk applies. The applicant's enhanced risk processes were used to identify and mitigate 125 risks related to the software and assay performance, and 60 risks related to cybersecurity considerations.

Risk analysis revealed 21 (b) (4)-related manufacturing and assay risks and 43 cybersecurity risks were considered "Not Acceptable" prior to mitigation. These were associated with unauthorized access to various parts of the system, source code or database that might allow loss or corruption of data, improperly patched software or firewalls or infected files, add-ons and logins. Other "Not Acceptable" risks were associated with alteration of data caused by inappropriate access to the system, operator error, incorrect information sent to the customer, sample ID tracking and data traceability issues. All risks were reduced to "As Far As Possible."

4. Software Requirements Specifications (SRS): Acceptable

In the original submission, the applicant provided the document (b) (4) Software Requirements Specification" (065_Attachment 4-5-5 SRS-(b) (4) IMUGEN.pdf) that describe the client/servicer application. The document includes 22 requirements for hardware, interface, software, performance, regulatory, system backup and restore, and other. Most requirements are too high level and do not include testable information. Requirements for workflow processes, boundary conditions and error recovery are missing.

In the original submission, the applicant did not provide a copy of the Software Requirements Specification document, which should clearly document the functional, performance, interface, design and development requirements.

Deficiencies were written for the Complete Response sent December 2015. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Questions #2, 8, 9, 11 and 12 for resolution of deficiencies related to software requirements and supported functionality.

Additional documentation was provided in the following:

- Complete Response received December 14, 2016
- Amendment received March 23, 2017
- Complete Response October 10, 2017

After the resolution of all deficiencies, the applicant provided updated software requirements specifications (023_Attachment-6.3_IT-CSV-IMD14-13-SRS &Doc Details.pdf). The format was updated to align with the risk analysis and traceability matrix, and ensure mitigations are captured.

The performance requirements for the system were optimized, including establishing the boundaries of the assay performance portion of the infrastructure from the IT business portion of the infrastructure. This was necessary because the applicant originally stated that the IT

infrastructure was beyond the scope of the (b) (4) software. However, this was found to be incorrect because all of the computers and servers are connected and potentially impact one another. To address some untestable requirements, some were changed and others were added to ensure the infrastructure can support the performance requirements of the (b) (4) software. The applicant hired an “FDA consultant” who reviewed the proposed testing. Updated test plans and risk management information were provided. Additional requirements related to security, restricting access, source code archival, (b) (4) database backup and restoration were also added.

The applicant confirmed that results are sent to clients manually by email in PDF format or as a .csv file via secure FTP. The applicant also confirmed that (b) (4) will not be compiled for commercial release, in contrast to claims in the original submission. The complete documentation package for the final version, Build 1.0.5.5, was provided. See Interactive Question #9 for details.

5. Architecture Design Chart: Acceptable

In the original submission, the applicant did not provide a detailed depiction of functional units and software modules, which may include state diagrams as well as flow charts. Deficiencies were written for the Complete Response sent December 2015. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Questions #2, 3 and 13 for resolution of deficiencies related to the system architecture. A software architecture chart was never provided, although FDA constructed a chart based on submission information, which appears in the Device Description Overview. A hardware architecture chart showing the network connections was provided and is included in Appendix 2: Device Description Details to explore the boundaries of the system for risk purposes.

Additional documentation was provided in the following:

- Complete Response received December 14, 2016
- Amendment received March 23, 2017
- Complete Response October 10, 2017

After the resolution of all deficiencies, the applicant provided an updated architecture document (021_Attachment-6.1_IT-CSV-IMD14-15-AD &Doc Details.pdf) that provides significantly more information about the (b) (4) architecture and database architecture, and a hardware network diagram (Section 2.4.2). Information about each of the components in the system was provided, including operating systems and hardware. The applicant also updated the (b) (4) database server, at FDA’s request, from an unsupported version of Windows (Windows Server (b) (4)) to Windows (b) (4). Migration testing documentation was provided. See Interactive Question #13 for details.

6. Software Design Specification (SDS): Acceptable

In the original submission, the applicant provided a software design specification document (066_Attachment 4-5-6 SDS-(b) (4) IMUGEN.pdf) for the (b) (4). The document includes the modules of the (b) (4) for Process Role, PCR Role, Report Role, Audit Role, and Admin Role. These each illustrate the control flow among the User, the UI, the Data Model and the Data Storage. The database schema is presented in Figure 1 on page 566. Definitions are included in Section 2.4 starting on page 569. All components are described by Field with included Notes and Type.

However, none of the Fields have specified measurable or testable values. There is no traceability from the requirements enumerated in SRS document (065_Attachment 4-5-5 SRS-(b) (4) IMUGEN.pdf) to this SDS document to describe how the requirements in the Software Requirements Specifications (SRS) are implemented.

Deficiencies were written for the Complete Response sent December 2015. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Question #4 for resolution of deficiencies related to the software design specifications.

Additional documentation was provided in the following, where the documentation was significantly updated.

- Complete Response received December 14, 2016
- Amendment received March 23, 2017
- Complete Response October 10, 2017

After the resolution of all deficiencies, the applicant provided significantly updated software design specifications (022_Attachment-6.2_IT-CSV-IMD14-14-SDS &Doc Details.pdf) with detailed workflow diagrams for each process role. The specifications are not constructed as traditional specifications with testable metrics, but rather as descriptive statements of functionality with screen shots of the corresponding (b) (4) software illustrating their implementation. This is likely because the SDS was reverse-engineered from the completed software program, rather than developed before the software was written. Through the resolution of deficiencies, error checking was added, including screen shots illustrating the error checking functionality. Additional information to support testing was added. Specifications for hardware to support the software needs were also added.

7. Traceability: Acceptable

In the original submission, the applicant provided a traceability document (067_Attachment 4-5-7 Imugen (b) (4) Traceability Analysis.pdf) that includes items for each of 22 high level requirements. "V&V Tests" in the form of references to Installation Qualification tests or Operational/Performance Qualification tests are included and associated hazards are identified. Traceability of requirements and specifications to testing and hazards is not comprehensive.

This is due in part to inadequately formulated requirements which are often vague and untestable as written, and use of test cases which are mostly limited to using valid values and workflow actions.

In the original submission, the traceability matrix provides traceability among identified clinical hazards and mitigations, requirements, specifications, and verification and validation testing in an enumerated manor.

Deficiencies were written for the Complete Response sent December 2015. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Questions #1 and 5 for resolution of deficiencies related to the traceability.

Additional documentation was provided in the following, where the documentation was significantly updated.

- Complete Response received December 14, 2016
- Amendment received March 23, 2017
- Complete Response October 10, 2017

After the resolution of all deficiencies, the applicant provided a significantly updated traceability matrix (026_Attachment-6.6_IT-CSV-IMD14-16-TM &Doc Details.pdf). The trace table includes headings for Risk ID, SRS Ref #, the actual software requirement language, the SDS #, the Architecture section #, V&V test cases and filenames, and an indication of Pass/Fail for the corresponding test case. The matrix was updated several times to address updates in any of the referenced design control documentation (i.e., requirements, specifications, testing, risk analysis).

8. Software Development Environment Description: Acceptable

In the original submission, the applicant provided the Life Cycle Development Plan (068_Attachment 4-5-8 Imugen (b) (4) Life Cycle Development.pdf) which included an overview of each software development phase. Four control documents (QA scripts) were listed for quality assurance and four process documents were listed that are stated to describe more formalized design control, change control management and verification and validation processes. These are shown in the figure below. The applicant stated that these will be used in future versions of (b) (4). This is acceptable.

The following table lists the control documents that were generated during the software development process, along with a description of each document.

- (b) (4) QA Script for January 11, 2013 – Testing QNS processing and resulting of QNS (b) (4) (Attachment 4-5-8-1)
- (b) (4) QA Script for February 14, 2013 – Testing report functions for Recipient Look-Back and (b) (4) Follow-up (Attachment 4-5-8-2)
- (b) (4) QA Script for February 22, 2013 – Change to import PCR templates and results in (b) (4) plate report functions (Attachment 4-5-8-3)
- (b) (4) QA Scripts for March 27, 2013 – Testing of IFA slide barcode implementation for slide creation and result entry (Attachment 4-5-8-4)

IMUGEN has since implemented a more formalized process for design control, change control management, and verification and validation to be used for future versions of (b) (4).

- | | | |
|-----------------------|---|----------------------------|
| • IT-FAC-PRO-1 | Computer System Design, Validation and Deployment | (b) (4) Attachment 4-5-8-5 |
| • IT-FAC-PRO-2 | Change Control | Attachment 4-5-8-6 |
| • IT-CSV-IMD14-06-IQ | (b) (4) Installation Qualification | Attachment 4-5-8-7 |
| • IT-CSV-IMD14-07-OPQ | (b) (4) Operational/Performance Qualification | Attachment 4-5-8-8 |

9. Verification and Validation Documentation: Acceptable

In the original submission, in the testing document “080_Attachment 4-5-9 Imugen (b) (4) Verification Validation.pdf” the applicant provided verification and validation information for the (b) (4) software. The applicant stated that “[s]ystem verification and validation were achieved by comparing outputs from each functional module to corresponding physical documentation such as shipping manifests, laboratory worksheets, and hard copy output of the (b) (4) instrument software.” The scope of these V&V activities is not clear, but appears to include only functional requirements and not performance requirements or any testing of error or abnormal conditions, or testing to ensure risk mitigations successfully reduce risk to acceptable levels.

In the original submission, the applicant did not provide a description of the validation and verification activities at the unit, integration, and system level, which should include the unit, integration and system level test protocols including the pass/fail criteria, and test report, summary and test results.

Deficiencies were written for the Complete Response sent December 2015. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Questions #2, 5, 10, 12 and 13 for resolution of deficiencies related to the verification and validation activities.

Additional documentation was provided in the following, where the documentation was significantly updated.

- Complete Response received December 14, 2016
- Amendment received March 23, 2017

- Complete Response October 10, 2017
- Amendment received November 20, 2017

After the resolution of all deficiencies, the applicant developed and performed several additional test protocols. Several interactions with the applicant focused on the use of Installation Qualification (IQ), Performance Qualification (PQ), and Operational Qualification (OQ) testing rather than more detailed unit testing, integration testing and systems level testing. IQ/PQ/OQ testing is generally black box testing, in that it tests the performance of the completed system. This type of testing often omits the type of white box testing that ensures that all error checking works correctly, that the individual software components meet their specifications and that the interface among components is comprehensive, complete and correct. The applicant was resistant to performing appropriate verification testing for the (b) (4) software, although additional testing related to error conditions and risk mitigations was performed. As described in Interactive Question #5, the testing strategy for Build 1.0.5.5 was revised to reference unit, integration and system level testing, although in most cases, the applicant just mapped existing testing to these labels. Because the specifications were developed by reverse engineering the software, they were not constructed in a manner to facilitate true verification testing such as unit level testing.

At this point, it appears that the benefits of getting this test to market outweigh the risks of forcing the applicant to undergo the lengthy process of fully reverse engineering the design specifications and testing schemes to ensure verification has been performed completely. Instead, focus was placed on developing an adequate risk process and using that to guide the review to ensure testing would adequately cover the identified risks. The applicant developed additional testing for error conditions and unexpected conditions related to user inputs and file imports from the (b) (4) instrument (see Interactive Questions #10 and 12), testing for database integrity and performance (see Interactive Question #2), and testing of cybersecurity mitigations for unacceptable risks (see Interactive Question #13).

The table below shows the originally-provided testing documentation, and the additional testing documentation developed and performed during this review. Five test documents were supplemented with an additional 14 testing documents.

Original Submission	Test document description	Document reference
	(b) (4) Installation Qualification	IT-CSV-IMD14-06-IQ (Rev. 1.0)
	(b) (4) Operational/Performance Qualification	IT-CSV-IMD14-07-OPQ
	Supplemental (b) (4) Validation	IT-CSV-IMD14-07OPQb
	(b) (4) Operational/Performance Qualification	IT-CSV-IMD14-07-OPQ
	Executed (b) (4) Operational Performance Verification	IT- (b) (4) SPT-8 (Rev. 1.1)

Final documentation developed	Newly provided documentation	
	(b) (4) v1.0.5.5 Validation Plan	IT- (b) (4) SPT-10
	(b) (4) v1.0.5.5 Validation Report	IT- (b) (4) SPT-19
	Executed (b) (4) User Interface Verification	IT- (b) (4) SPT-14
	Executed (b) (4) PCR File Verification Test Protocol	IT- (b) (4) SPT-11
	Executed (b) (4) Unit Test Verification	IT- (b) (4) SPT-15
	(b) (4) Unit Test Report	IT- (b) (4) SPT-18
	Executed (b) (4) Installation Qualification	IT- (b) (4) SPT-9
	(b) (4) Database Server Migration Support Software Validation Plan	IT- (b) (4) SPT-22
	(b) (4) DB Availability Test Protocol	IT- (b) (4) SPT-17
	Cybersecurity test protocol	IT- (b) (4) SPT-24
	(b) (4) Software System Test Plan	IT- (b) (4) -1
	(b) (4) Software Verification Test Report	IT- (b) (4) -2
	(b) (4) Server Migration Plan	IT- (b) (4) SPT-29
	(b) (4) DB Migration Test Report	IT- (b) (4) SPT-31

10. Revision Level History: Acceptable

In the original submission, in the revision history (081_Attachment 4-5-10 Imugen (b) (4) revision level history.pdf) the applicant provided a revision level history which included updates that have been made through 8/28/2013.

Based on changes requested to correct an unresolved anomaly, the applicant provided an updated revision history (Attachment_14.1-IT-CSV-PDF-42&DocDetails.pdf) and updated design control documentation to support launch with version Build 1.0.5.5. See Interactive Questions #6 and 9.

11. Unresolved Anomalies (Bugs or Defects): Acceptable

In the original submission, in the document Unresolved Anomalies document (082_Attachment 4-5-11 Imugen (b) (4) Unresolved Anomalies_04172015.pdf) the applicant provided unresolved anomalies. Only one unresolved anomaly was reported:

“PCR Results import - The PCR Results import template to be printed does not currently highlight Ct values which exceed a specified threshold. The laboratory technician performing the experiment cross checks the output of the (b) (4) template with the (b) (4) printout and is trained to identify Ct values over specified threshold which would require the sample to be retested.

Accordingly, as there is a manual check of the Ct values performed, this anomaly does not impact the safety or efficacy of the product.”

Because this anomaly could be associated with a false negative if a sample is not retested when it should be, the applicant was requested to correct the anomaly. Originally, the anomaly and mitigation are not included in the hazard analysis, and no requirements were added to address this. In the amendments received December 14, 2016 and March 23, 2017, the applicant explained that a CAPA was initiated and a software change added to flag this situation. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Question #6 for resolution of deficiencies related to the unresolved anomalies.

12. Cybersecurity: Acceptable

In the original submission, the applicant did not provide information on Cybersecurity. This includes, but is not limited to, the following facets of information security with respect to communications features of the device and associated software: confidentiality, integrity, availability and accountability.

- Confidentiality assures that no unauthorized users have access to the information.
- Integrity is the assurance that the information is correct - that is, it has not been improperly modified.
- Availability suggests that the information will be available when needed.
- Accountability is the application of identification and authentication to assure that the prescribed access process is being done by an authorized user.

Deficiencies were written for the Complete Response sent December 2015. See Appendix 1: Sponsor/Applicant Interactions and Communications, Interactive Questions #5, 7 and 13 for resolution of deficiencies related to cybersecurity.

Additional documentation was provided in the following, where the documentation was significantly updated.

- Complete Response received December 14, 2016
- Amendment received March 23, 2017
- Complete Response October 10, 2017
- Amendment received November 20, 2017

After the resolution of all deficiencies, the applicant provided a new risk management document specific to cybersecurity (046_Attachment-12.1_DOC-RSK-9_Cybersecurity Risk Assessment.xlsx) and additional testing for security-related risks (002_Attachment-1.1_IT-(b) (4)-SPT-24.pdf). A more detailed network diagram of the system was provided to assist in the identification of cybersecurity related risks, because the applicant has several computers and servers (b) (4). The IT business network is not completely isolated from the computers used to perform the assays. Interactions were required to help the applicant

understand that simply adding a firewall was not an assurance that risks would be mitigated; instead, the applicant needed to specifically link identified security risks to the individual mitigations. Several references were provided to the applicant, including FDA's premarket and postmarket cybersecurity guidance documents. Finally, the applicant developed testing to ensure that the identified risk control measures were appropriate. Detailed interactions can be found in the Interactive Questions.

6 Reviewer Notes and Recommendations

a) Notes Related to the Review

- Significant interactive review occurred for both the NAT and AFIA submissions. Software and instrumentation questions for each overlap about 90%, although some questions were unique to each (e.g., PCR-specific questions for the NAT submission). While attempts were made to keep the numbering of the common questions the same, this was not possible.
- Due to an oversight, some common software and instrumentation questions were not included in the AFIA Information Request emailed February 24, 2017. The missing questions were however, included in the corresponding NAT IR sent February 17, 2017. Rather than send the questions separately, the issues were resolved in this memo (NAT) and the resolution then copied to the AFIA memo to address each question.
- Because the AFIA submission had an extra risk document, only the AFIA submission explored the new risk procedure, LAB-QA-62, that now applies to all risk activities at Oxford Immunotec. Summary information about the procedure is contained in this memo, but detailed information is explored in the AFIA memo.

b) Notes of Disagreement

Specific software deficiencies were identified in September, 2015 but were not provided to the applicant until early 2017. This caused a significant delay of *over 16 months* in the applicant's ability to address the actual software and instrumentation deficiencies in their system. Specific deficiencies should be provided as early in the review cycle as possible.

c) Notes to Future Reviewers

Documentation changed significantly over the course of this review and many documents have been obsoleted. Refer to the October 10, 2017 (b) (4) Submissions Table" (050_Attachment-13.3(b) (4) submissions table.pdf) from Amendment 32 for a list of all documents ever provided for this submission related to software and instrumentation. The table indicates when each was provided and if it is obsolete. **This table should be consulted before assuming any provided document is the latest version upon which this licensure is based.** Additionally, final risk documentation that applies to all risk procedures was provided in Amendment 33 of the AFIA submission and summarized in this memo.

d) Reviewer Recommendation

When this submission was received, it was clear that the applicant did not have an adequate quality system in place when the design control documentation was developed. The quality of the documentation improved over the two Complete Responses and other information requests, especially after a consultant was retained to assist in development of adequate processes. FDA participated in several interactive telecons and emails to provide supportive, guiding information on the applicant's evolving risk procedures. The biggest issues and improvements include:

- Risk processes and documentation improved significantly after the applicant developed a risk procedure aligned with ISO 14971 and harmonized the separate risk assessments for the NAT and AFIA assays.
- Verification and validation was initially limited to IQ and OPQ testing, which does not fully exercise the system. Additional testing was developed and completed to better align with unit, integration and system testing as outlined in FDA's premarket guidance document.
- No cybersecurity risk activities had been performed; a new cybersecurity risk assessment and cybersecurity testing have been implemented.

All deficiencies have been adequately resolved.

Reviewer Recommendation: Approvable. The following should be sent as described in Interactive Question #13 and reproduced below. No response is required.

In the amendment (001_Response to IR Received 9Nov2017_NAT.pdf) received November 20, 2017 in response to FDA Question 3, you provided the versions of cybersecurity programs in use and stated that these are the latest version released and that you adhere to your policy of receiving automatic updates. Please note that at the time your response was prepared, both programs were currently advertised as having later versions of software than you provided. Therefore, you should ensure that your mechanism for receiving automatic updates is working correctly. No further response is required.

7 Appendix 1: Sponsor/Applicant Interactions and Communications

This appendix contains the resolution of all deficiencies in the form of Interactive Questions in “Question, Response, Comment” format.

The following questions were provided in a Complete Response letter dated September 29, 2015.

1. **FDA Question 29:** *In your BLA you have provided Hazard Analysis document (064_Attachment 4-5-4 (b) (4) Hazard Analysis.pdf.) that includes potential hazards, severity estimation, hazard mitigation and updated severity estimation after hazard mitigation. However, information such as cause(s) of the hazard and/or verification that the method of control was implemented correctly is not included in your table. Your Hazard Analysis document should be in the form of an extract of the software-related items from a comprehensive risk management document, such as the Risk Management Summary described in ISO 14971. For example, Failure Mode and Effects Analysis (FMEA) can be one of the approaches that could be utilized to identify the hazards, their corresponding validation and verification, and construction of the table accordingly. Therefore please provide an updated table based on FMEA and ISO 14971 methodologies. For further information, please refer to FDA software guidance document, <http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm089593.pdf>. Please also consult a possible example of FMEA table available at: <http://asq.org/learn-about-quality/process-analysis-tools/overview/fmea.htm>.*

Response: In the amendment received December 14, 2016 in response to FDA Question 29, the applicant provided risk analysis information including reference to the risk analysis, (b) (4) Risk Analysis IT-CSV-PDF-41.” The response was inadequate.

Comments: The following was sent to the applicant on February 17, 2017 as new FDA Question 17:

In your NAT Amendment response received December 14, 2016 in response to FDA Question 29 and in your AFIA Amendment received December 13, 2016 in response to FDA Question 34, you provided risk analysis information including reference to the risk analysis, (b) (4) Risk Analysis IT-CSV-PDF-41.”

- a. *In your response, you stated that the risk management document “[r]eferences mitigation plan, documented in SRS.” The file includes mitigations, but no numerical traceability from the risk ID to the SRS. Please provide this traceability. The Traceability Matrix “IT-CSV-IMD14-16-TM” embedded in your response document references Risk IDs that appear to be the Risk IDs in this document, but this is not explicitly stated. Please clarify this and provide updated documentation.*
- b. *This file does a better job of identifying individual risks than the document “B. microti AFIA Device Risk Analysis” (Attachment- 33.5_LAB-DSGN-5 .xlsx) and*

nicely allows the reader to use filtering to explore the effects of different causes and the scope of different mitigations. However, harm is not explicitly stated and too many “Potential Effects” are listed for each Risk ID. Some “Hazards” include cause information. Similar to the Device Risk Analysis, please update and provide this analysis to align better with ISO 14971 to leverage its benefits.

- c. *This file only references mitigations by “design.” Where have you documented the mitigations using other means; for example, in labeling that includes hazards or instructions? Please provide this information, including traceability from the individual mitigations to the corresponding user documentation where appropriate. This is necessary to review your proposed mitigations for risks that you have controlled through means other than by design.*

Response a: In the amendment received March 23, 2017 in response to FDA Question 17, the applicant provided an updated Traceability Matrix IT-CSV-IMD14-16-TM, (b) (4) Traceability Matrix” (Attachment 15.2) with the requested traceability information. This is adequate.

Response b: In the amendment received March 23, 2017 in response to FDA Question 17, the applicant provided an updated FMEA risk analysis (Attachment_15.1-IT-CSV-PDF-41.xlsx) to better align with ISO 14971. The applicant refers to this as an “FMEA,” which it is not. It is table with some FMEA columns and some ISO 14971 columns but lacking sufficient information for either. There continues to be misunderstandings, as described in the Comments section below.

Response c: In the amendment received March 23, 2017 in response to FDA Question 17, the applicant stated that other mitigations requested are included in LAB-DSGN-11, “NAT Device Risk Analysis” and LAB-DSGN-5, “AFIA Device Risk Analysis”. The software specific risks are addressed in Attachment 15.1, IT-CSV-PDF-41, (b) (4) Risk Analysis”. These updated documents were also referenced in the AFIA submission (BL125589) and the same concerns exist. Additional questions on content and harmonization are described in the Comments section below.

Comments: The following was sent to the applicant on April 14, 2017 as new FDA Question 9, and was included in the Complete Response letter sent June 13, 2017 as FDA Question 9 (but numbered as FDA Question 11):

Risk processes: In the NAT amendment received March 23, 2017 in response to FDA Question 17, you included updated risk documentation. There is some better alignment with ISO 14971 “Medical device – application of risk management to medical devices,” but the table in the (b) (4) Hazard Analysis (Attachment_15.1-IT-CSV-PDF-41.xlsx) is not an FMEA and does not align with terminology used in ISO 14971. Consider the following:

- a. *What does your “Probability” correspond to in ISO 14971? It is not clear what your “Probability” refers to so it is difficult to assess the risk table. The “Scoring System” tab refers to Likelihood, not Probability. For example, Risk 2 “password hacked” has a Probability of 4 which is high, so it is unclear if this refers to P1 or P2 or the combination. In the “Front page” tab of the NAT Risk Analysis (Attachment_22.1-LAB-DSGN-11.xlsm), the Likelihood definitions specifically refer to failures. This suggests that your probability is still focused only on P1 and does not include probability of a hazardous situation leading to harm. Please revisit your risk management processes and provide a clear description of your processes and how they align with ISO 14971. State explicit the scope of “probability” in your documentation and ensure your risk documentation includes all aspects of probability. As a start, we suggest removing the notion of “failure” from your definitions.*
- b. *What is your process to determine the new level of Probability as the result of the identified mitigation(s)? Please provide your risk documentation that describes how this is determined.*
- c. *Please refer to comments made regarding the “Babesia microti AFIA device risk analysis” (Attachment_13.1-LAB-DSGN-5.xlsm) and its alignment with ISO 14971, and ensure that you make the same changes to both risk documents for consistency regarding clear traceability with hazards, hazardous situations, causes, traceability to mitigations in manuals and SOPs, etc. We recommend that you should harmonize the format you are using to capture risk information so that all use the same terminology and methods, or you should provide a clear description and process for each that allows independent review.*

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 11 on PDF page 25, the applicant provided updated risk management information.

- (a) The applicant stated that they revised their risk assessment processes to comply with ISO 14971 in LAB-MEM-38, “Memo on Risk Management” (Attachment 6.9). Several changes in their processes were made, such as ensuring potential causes related to a specific hazard and foreseeable events are documented with specific links to outcome malfunctions. Hazardous situations are clarified and assessed according to ISO 14971, probability of harm from hazardous situations has been added, a “risk probability number” is added, and mitigations are assessed individually to determine effects on risks separately. Risks to harm from both manufacturing process failure and assay process failure are included. The risk processes are significantly improved from previous submissions. A note about a conflict with the term, “Risk Probability Number” should be sent to clarify any confusion – see the Comments section.
- (b) Methods to determine the new probability level are included in the memo, with examples in Section 3. This is adequate.

(c) The applicant stated that the risk formats were harmonized as requested. This is adequate.

Comments: The following was emailed to the applicant on November 9, 2017 as new FDA Question 4.

In the complete response, in your Memo on Risk Management (029_Attachment-6.9_LAB-MEM-38& Doc Details.pdf) you described updates to your risk assessment methods to comply with ISO 14971 and provided clear instructions and examples. As a minor note, you defined “Risk Probability Number (RPN)” as the product of Severity, P1 and P2. Calculating risk this way is acceptable. However, please be aware that the acronym “RPN” is used heavily in industry as “Risk Priority Number” and refers to a different concept. To avoid confusion, you should refer to your risk calculation differently (perhaps “Risk Number (RN)”), or simply call it what it is: Risk.

Response: In the amendment (001_Response to IR Received 9Nov2017_NAT.pdf) received November 20, 2017 in response to FDA Question 4, the applicant stated that the terminology has been modified and documents will refer to “Risk Number” and “RN”.

Comments: The response is acceptable. Resolved.

2. **FDA Question 30:** *In your BLA submission you provided Software Requirements Specifications (SRS) in document (b) (4) Software Requirements Specification” (065_Attachment 4-5-5 SRS(b) (4) IMUGEN.pdf) that describes the client/servicer application. The document includes 22 requirements for hardware, interface, software, performance, regulatory, system backup and restore, etc. Most requirements are too high level and do not include testable information. The requirements for workflow processes, boundary conditions and error recovery are missing. Please provide an updated copy of the Software Requirements Specification document, which should clearly document the functional, performance, interface, design and development requirements.*

Response: In the amendment received December 14, 2016 in response to FDA Question 30, the applicant provided an updated SRS where information has been inexplicably removed. The response was inadequate.

Comments: The following was sent to the applicant on February 17, 2017 as new FDA Question 16:

In your original submission in the software requirements document (Attachment 4-5-5 SRS-(b) (4) IMUGEN) in Section 2.5 you provided Performance Requirements. In your NAT Amendment response received December 14, 2016 in response to FDA Question 30 and in your AFIA Amendment response received December 13, 2016 in response to FDA Question 35 you provided an updated Software Requirements Specification document where all

performance requirements were removed. Please clarify why entire sections of requirements have been removed, and update and provide your requirements documentation to ensure all requirements are correctly captured.

Response: In the amendment received March 23, 2017 in response to FDA Question 16, the applicant stated that requirements “relevant to IT infrastructure for general lab operation ... is beyond the scope of the (b) (4) software” and were removed. Unfortunately, performance requirements are very relevant for their throughput and capacity claims, which don’t appear in the requirements. These should be added back, with testable criteria, and corresponding test results to show that the underlying infrastructure can support the device intended use.

Comments: The following was sent to the applicant on April 14, 2017 as new FDA Question 1, and was included in the Complete Response letter sent June 13, 2017 as FDA Question 6:

Performance requirements for (b) (4) hardware and software: In the NAT amendment received March 23, 2017 in response to FDA Question 16, you stated that requirements “relevant to IT infrastructure for general lab operation ... is beyond the scope of the (b) (4) software and were removed.” This is not reasonable because the (b) (4) software requires proper operation of the underlying infrastructure to meet its intended use. Your documentation has inconsistently described the components of the system, and it is not clear what hardware supports the (b) (4) software and database functionality. You should include requirements related to the infrastructure that is necessary to support the intended use of the device for both the NAT and AFIA assays. This appears to include the components in the Hardware Network Diagram in section 2.3.2 in your Architectural Design document provided in Attachment 29.4 of your response received December 14, 2016, and any other relevant components not identified in this diagram.

- a. Please clarify all of the required components for your system, including PCs, printers, network connections, etc. Explicitly identify the boundaries of the system with respect to your corporate network.*
- b. Please include all requirements related to required capacity for throughput, database capacity and accessibility, connectivity, uptime, etc., in order for the underlying infrastructure system to meet the required needs of the system. These requirements should include testable metrics to ensure that they can be met.*
- c. Include all test plans, test results and verification and validation testing for these performance requirements.*
- d. Update your traceability matrix to include this information.*
- e. Update your risk documentation to include risks associated with the performance needs of the system, and include the mitigations you implemented to reduce those risks to acceptable levels.*

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 6 on PDF page 7, the applicant provided additional information.

- (a) Architectural design information and updated components of the system were provided to illustrate system boundaries and facilitate development of the applicant's risk documentation.
- (b) Requirements were updated and untestable requirements were changed to address the issues. Untestable specifications were corrected and retested. Additional requirements were added to ensure the infrastructure can support (b) (4) performance needs.
- (c) An FDA consultant was hired who reviewed testing of performance requirements; updated test plans and results were provided.
- (d) Updated traceability was provided.
- (e) Risk documentation was updated with performance-related risks and countermeasures implemented to reduce risk to acceptable levels.

Comments: The response is acceptable. Resolved.

3. **FDA Question 31:** *You have not provided an "Architectural Diagram" that should include a description of the software system partitioned into its functional subsystems, incorporating a description of the role that each module plays in fulfilling the software requirements. Please provide an Architectural Diagram of your software. It is recommended that you consult ISO 62304 (Medical device software - Software life cycle processes) to prepare your software documentation and conduct testing.*

Response: In the amendment received December 14, 2016 in response to FDA Question 31, the applicant provided an updated architecture diagram in Attachment 29.4.

Comments: This response is acceptable. Resolved.

4. **FDA Question 32:** *You have provided a software design specification (SDS) document (066 Attachment 4-5-6 SDS-(b) (4) IMUGEN.pdf) for the (b) (4). The document includes the modules for the (b) (4) Process Role, PCR Role, Report Role, Audit Role, and Admin Role. These each illustrate the control flow among the User, the UI, the Data Model and the Data Storage. The database schematic is presented in Figure 1 on Page 566, definitions are included in Section 2.4 starting on Page 569, and all components are described by Field with included Notes and Type. However, none of the fields have specified measureable or testable values. There is no traceability from the requirements enumerated in document "065_Attachment 4-5-5 SRS-(b) (4) IMUGEN.pdf" to this SDS document to describe how the requirements in the Software Requirements Specifications (SRS) are implemented. Please add the missing requirements to your software requirement specifications, including all step-by-step workflow requirements, for both AFIA and NAT, and provide all updated design control documentation that is affected.*

Response: In the amendment received December 14, 2016 in response to FDA Question 32, the applicant provided an updated SDS in Attachment 29.5 that is missing testable details and test case information. The response was inadequate.

Comments: The following was sent to the applicant on February 17, 2017 as new FDA Question 18:

In your NAT Amendment response received December 14, 2016 in response to FDA Question 32 and in your AFIA Amendment received December 13, 2016 in response to FDA Question 37, you stated that for the (b) (4) software, you included an updated Software Design Specification and Traceability Matrix that “contain measurable and testable values.” Thank you for providing these updates and the detailed information. Several Risk ID/SRS entries in your traceability table do not trace to software design specifications, and some trace to testing that does not appear to relate to the corresponding risk/requirement. This makes it difficult to assess the adequacy of your proposed mitigations. Note that necessary testing at the unit, integration and system level is often different and more comprehensive than qualification testing.

- a. For example, Risk ID 24/SRS 24 addresses a risk that PCR results might be modified. No design information was provided on how this would be performed, and the referenced V&V test cases don't appear to test any attempts to modify PCR results to ensure the risk is properly mitigated. The tests are "Script (b) (4) and "Script (b) (4) Step (b) (4) is (b) (4) How do these tests verify that software prevents any modification of the PCR results? Please provide the correct documentation.*
- b. Risk ID 34/SRS34 involves risk of loss of sample origin, but has no associated SDS. The requirement itself is vague and the corresponding testing refers to step (b) (4) of a test script. However, the test script ends after (b) (4) steps. Please clarify the risk and requirement, and provide corrected documentation.*
- c. Risk ID 39/SRS 39 refers to a test script that was not provided. This portion of the testing documentation is blank. Please provide the correct documentation.*
- d. Risk ID 49/SRS 49 does not include testable information and is not traceable to an SDS. Some of the relevant information appears in the test case; however, specifics of the device design should be captured in the requirements and specification documentation, and not documented solely in testing documentation. Please update your SRS and/or SDS with the appropriate design information accordingly, and provide the correct documentation.*
- e. Risk ID 51/SRS 51 and Risk ID 52/SRS 52 specify software by version number “or later.” Your requirements should apply to a specific version or versions with testing corresponding to those versions. Please remove reference to “or later” for any*

software used in the system, including in any labeling, and ensure explicit versions are referenced.

This is not a complete list of issues, but a representative sample of concerns. Please review and update the remainder of the document for traceability and accuracy issues. For requirements that have no corresponding design specification, clarify why an SDS is not necessary.

Response: In the Amendment received March 23, 2017 in response to FDA Question 18, the applicant addressed each of the Risk/SRS pairs enumerated in the FDA Question: (a) was clarified, (b) has been corrected with correct validation, (c) supplemental testing was provided. For (d), testing details were augmented, (e) references to “or later” were removed, and traceability and SRS documents were updated accordingly.

Comments: The response is acceptable. Resolved.

Response 2: In the amendment received December 14, 2016 in response to FDA Question 32, the applicant provided an updated SDS in Attachment 29.5 that does not contain explicit design specification information traceable to requirements. The response was inadequate.

Comments 2: The following was sent to the applicant on February 17 as new FDA Question 19:

In your NAT Amendment response document received December 14, 2016 in response to FDA Question 32 and in your AFIA Amendment response received December 13, 2016 in response to FDA Question 37, you provided a Software Design Specification document. This version 1.1 of the document does not appear to be substantially changed over version 1.0 provided in your original submission. Many screen shots are presented but it is not always apparent what has changed from one screen to the next, what is expected to appear on the screen, what information the user entered, and what are the system responses when the user does something unexpected. Each of these specifications should include explicit text about what should appear on the screen and what the device and/or user is expected to do. It is not sufficient to collect screen shots of a completed system and state that these encompass a software design specification without additional information. It is not reasonable to expect a designer/tester/reader to compare successive screen shots to determine for themselves what has changed between the two screen shots. This increases the opportunity for misunderstanding, inadequate design and testing.

Please augment the information in your Software Design Specification with explicit testable information. Some of this information appears to exist in various testing documents and SOPs, but you have not provided a comprehensive collection of software design specifications which describes how the requirements in the Software Requirements Specifications (SRS) are implemented in a clear and unambiguous manner. Please provide this updated information.

Response: In the Amendment received March 23, 2017 in response to FDA Question 19, the applicant provided updated versions of the Risk Analysis, Traceability Matrix, SRS and SDS referred to above (Attachments 15.1, 15.2, 15.3 and 18.1, respectively). The Software Design Specification contains significantly more detailed and testable information to accompany the previous screen shots, and the corresponding testing is provided and included in the other design documentation.

Comments: The response is acceptable. Resolved.

5. **FDA Question 33:** *You have provided a traceability document (067_Attachment 4-5-7 IMUGEN (b) (4) Traceability Analysis.pdf) that includes items for each of 22 high level requirements. The “Verification and Validation Tests” in the form of references to Installation Qualification tests or Operational/Performance Qualification tests are included and associated hazards are identified. However, the traceability of requirements and specifications to testing and hazards are not comprehensive. This is due in part to inadequately formulated requirements, which are often vague and untestable as written, and the use of test cases that are mostly limited to using valid values and workflow actions.*
- a. *Please provide verification and validation information for all software requirements (including missing requirements mentioned in other deficiencies), which should include the unit, integration and system level test protocols with pass/fail criteria, and test report, summary and test results.*
 - b. *Please provide traceability information described at the detail level of individual software requirements rather than the high level software requirements, R1-R22. This includes traceability among identified clinical hazards and mitigations, requirements, specifications, and verification and validation testing in an enumerated manner.*

Response: In the amendment received December 14, 2016 in response to FDA Question 33, the applicant provided an updated traceability matrix in Attachment 29.3. The applicant enumerated each of 58 Risk IDs and corresponding requirements, and stated that testing information appears in relevant IQ and OPQ reports. IQ and OPQ testing are not the same as verification and validation testing outlined in part (a); the applicant did not provide adequate testing documentation. The response was inadequate.

Comments: The following was sent to the applicant on April 14, 2017 as new FDA Question 2, and was included in the Complete Response letter sent June 13, 2017 as FDA Question 7:

Verification and validation testing: *In the NAT amendment received December 14, 2016 in response to FDA Question 33, you provided an updated traceability matrix in Attachment 29.3 and referred to IQ and OPQ testing. The testing is incomplete. Note that process validation testing (Installation Qualification (IQ), Operational Qualification (OQ) and Performance Qualification (PQ)) testing are not the same as verification and validation testing outlined in part (a). Please refer to FDA’s guidance document, “General Principles*

of Software Validation,” with a particular focus on section 5.2.5, located at <https://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm085371.pdf>. As outlined in the premarket software guidance, “Guidance for the Content of Premarket Submissions for Software Contained in Medical Devices,” please ensure that you provide unit, integration and system level test protocols, including pass/fail criteria, test report summary, and tests results. It is difficult to assess the adequacy of a test script by viewing only raw test steps without a description of the test plan and protocol and a summary of results.

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 7 on PDF page 12, the applicant provided Attachment 13.3, (b) (4) Submissions Table” that indicates all documents sent to the FDA with their date of submission, the relevant attachment number, the relevant software version, and whether the document is now obsolete. This is extremely helpful because multiple versions of documents have been sent over the last two years. Table 7.1 on page 14 lists all the individual types of tests performed, an explanation of the test, justification, and test activity (with file name).

The testing plan and strategy for v1.0.5.5 was provided, and was revised to include unit, integration, and system level testing. The updated test plan and test report were provided for version Build 1.0.5.5 (024 Attachment-6.4_IT(b) (4)-1 &Doc Details.pdf, 025_Attachment-6.5_IT-(b) (4)-2 &Doc Details.pdf) includes the testing types and computers involved. All requirements were met.

Comments: The following was emailed to the applicant on November 9, 2017 as new FDA Question 1.

In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 7 on PDF page 12, you provided a table of testing activities. We were unable to locate the test protocol results that correspond to IT(b) (4)-SPT-24 (b) (4) CyberSecurity Test Protocol” and IT-(b) (4)-SPT-17 (b) (4) System Uptime Test Protocol.” Please provide these test case results. This is necessary to confirm the claim that all requirements have been correctly implemented.

Response: In the amendment (001_Response to IR Received 9Nov2017_NAT.pdf) received November 20, 2017 in response to FDA Question 1, the applicant stated that the test results were inadvertently omitted, and provided the requested information. The testing is adequate.

Comments: The response is acceptable. Resolved.

6. **FDA Question 34:** *In the document, “082_Attachment 4-5-11 IMUGEN (b) (4) Unresolved Anomalies_04172015.pdf” you provided one unresolved anomaly: “PCR Results import - The PCR Results import template to be printed does not currently highlight Ct values which exceed a specified threshold. The laboratory technician performing the experiment cross*

checks the output of the (b) (4) template with the (b) (4) printout and is trained to identify Ct values over specified threshold which would require the sample to be retested. Accordingly, as there is a manual check of the Ct values performed, this anomaly does not impact the safety or efficacy of the product.” *This anomaly could be associated with a false negative if a sample is not retested when it should be. This anomaly and mitigation information was not included in the hazard analysis, and no requirements were added to address this. Please correct this anomaly and update the associated design documentation.*

Response: In the Amendment received December 14, 2016, the applicant stated that this was not an anomaly in software, but an issue caused by a technician reviewing paper records. The non-conformance was raised and a CAPA initiated with retraining. Change control was implemented in the FMEA Risk Analysis (Attachment 29.1).

This question was additionally asked in the February 17, 2017 IR as FDA Question 21. In the Amendment received March 23, 2017, the applicant provided an updated SDS and additional validations in the traceability matrix supporting new risk R26a to address this.

Comments: The response is acceptable. Resolved.

7. **FDA Question 35:** *You did not provide information on Cybersecurity related to all instruments, hardware and software incorporated into the system, including Off-the-Shelf components. The (b) (4) system includes at least (b) (4) types of servers and multiple workstations/clients, at least (b) (4) of which has established connectivity to the outside world. Please provide information on the Cybersecurity aspects of your device, including, but not limited to, the following facets of information security with respect to communication features of your device, associated software and other required components: confidentiality, integrity, availability and accountability. Confidentiality assures that no unauthorized users have access to the information. Integrity is the assurance that the information is correct - that is, it has not been improperly modified. Availability suggests that the information will be available when needed. Accountability is the application of identification and authentication to assure that the prescribed access process is being done by an authorized user.*

Response: In the amendment received December 14, 2016 in response to FDA Question 35, the applicant provided an Information Technology Security Policy in Attachment 29.6 that is not related to security concerns during device operation. The response was inadequate.

Comments: The following was sent to the applicant on February 17, 2017 as new FDA Question 20:

In your NAT Amendment response received December 14, 2016 in response to FDA Question 35 and in your AFIA Amendment received December 13, 2016 in response to FDA Question 39 with respect to cybersecurity, you provided the document, “Information Technology Security Policy, IT-SEC-POL-1.” You stated that this describes “control of confidentiality information and accountabilities.” This policy appears to apply to your corporate networks

and business policies rather than for the device itself. Please note that you should identify risks associated with not only confidentiality, but integrity and availability, and take steps to reduce risk that device functionality is intentionally or unintentionally compromised by inadequate cybersecurity considerations. The (b) (4) system appears to include at least (b) (4) types of servers and multiple workstations/clients, at least (b) (4) of which has established connectivity to the outside world. Your risk documentation appears to contain some mitigations for potential cybersecurity risks, although you have not identified many of the possible causes to demonstrate that these mitigations would be adequate.

- a. Please refer to the FDA guidance and provide updated cybersecurity information for your device to address the elements listed in the guidance: “Content of Premarket Submissions for Management of Cybersecurity in Medical Devices” located at <http://www.fda.gov/downloads/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm356190.pdf>. This should include, in part, the following: hazard analysis, mitigations, and design considerations pertaining to intentional and unintentional cybersecurity risks associated with your device, and a traceability matrix that links your actual cybersecurity controls to the cybersecurity risks that were considered.*

Please describe your process for identifying and evaluating new operating system patches and other updates to off-the-shelf software and integrating patches and updates into your device.

Response: In the Amendment received March 23, 2017 in response to FDA Question 20, the applicant stated the referenced information was reviewed. In response, the applicant created a “Business Continuity and Disaster Recovery Plan” (Attachment 20.1 Attachment_20.1-DOC-POL-1.pdf) that focuses on business risk and includes data backup and recovery plans. The applicant also provided a substantial update to the “Information Technology Security Policy” (Attachment_20.2-IT-SEC-POL-01&DocDetails.pdf) that includes policies for accounts management, password management, encryption, data security, and software patches and updated, including antivirus updates. The applicant also pointed to the updated (b) (4) Risk Analysis” (Attachment_15.1-IT-CSV-PDF-41.xlsx). These are not adequate to answer the questions posed.

The applicant has not provided documentation aligned with the FDA guidance document. The risk management should include entries for all identified cybersecurity related risks to link these risks to the mitigations implemented, but this has not been done.

Comments: The following was sent to the applicant on April 14, 2017 as new FDA Question 10, and was included in the Complete Response letter sent June 13, 2017 as FDA Question 10 (but numbered as FDA Question 12):

Cybersecurity considerations: In the NAT Amendment received March 23, 2017 in response to FDA Question 20, you provided several documents including an updated (b) (4) Risk Analysis” (Attachment_15.1-IT-CSV-PDF-41.xlsx). Please note that we assess the adequacy of your cybersecurity features based on the threats and vulnerabilities you identify in your risk assessment. Without your analysis and identification, it is difficult for us to determine if the mitigations you implement are adequate. We do not have a clear picture of the client server and database components and connectivity to other systems. We see mention of some mitigations and some evidence of threats in several documents, but you have not provided a comprehensive view of the security risks to your system. The following suggest that the analysis activities we requested and described in the cybersecurity premarket guidance have not occurred.

- Your system is networked but you have no requirements or specifications related to connectivity or use of a firewall. You included a firewall in the Hardware Network Diagram in your Architectural Design document in Attachment 29.4 of your response received December 14, 2016, but it is not referenced in your risk documentation. You have not identified which risks might be addressed by use of a firewall, and the residual risks. You have not identified vulnerabilities related to this architecture.*
- You reference antivirus updates in your “Information Technology Security Policy” (Attachment_20.2-IT-SEC-POL-01&DocDetails.pdf) but you have not identified the vulnerabilities for which this mitigation would be effective. It also mentions physical security, but it is not clear if or how this applies to access to the software or hardware.*
- Some features that represent suggest security vulnerabilities were not included; for example you mention USBs in the “Information Technology Security Policy” but you have not discussed the risks of allowing an open USB port.*
- You have not identified functionality on the computer that should be restricted to limit exposure (e.g., disabling access to various unnecessary programs, unauthorized access through unattended workstation availability, etc.). Can users access the internet on the computer used to access the (b) (4) software? Can a user boot from a USB and alter the system? Can a user replace the (b) (4) software with an altered copy? Many scenarios related to misuse have not been explored.*

As requested previously, please perform the analysis described in the guidance, “Content for Premarket Submissions for Management of Cybersecurity in Medical Devices” and updated your design documentation accordingly.

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 12 on PDF page 27, the applicant provided requested information and stated that their design documentation was

updated to align with the analysis described in the premarket cybersecurity guidance document, as outlined on page 32.

(a) The applicant stated that a full review of security risks was conducted using the new risk management procedure (Attachment 6.9) and documented in the cybersecurity risk analysis DOC-RSK-9, "Cybersecurity Risk Analysis" (Attachment 12.1). Traceability to associated design control documentation was provided. The response document provides a good overview of the analysis.

(b) The applicant clarified the vulnerabilities and relevance of the document in Tables 12.4 and 12.5 on page 30.

(c) The applicant stated risks of unsecured USBs and other external device ports is included in the Cybersecurity Risk document, DOC-RSK-9 (Attachment 12.1) and enumerated in Table 12.6 on page 31.

(d) The applicant provided the Cybersecurity Risk Assessment (DOC-RSK-9, Attachment 12.1) that includes risks and appropriate mitigations for potential computer misuse. (b) (4) vulnerabilities were identified and discussed in Table 12.7 on page 32.

Comments: The response is acceptable. Resolved.

8. **FDA Question 36:** *In the document 065_Attachment 4-5-5 SRS-(b) (4)_IMUGEN, you have stated that "When testing and data collection is complete, laboratory managers will use the software to produce reports of sample results which are electronically transmitted to the submitting entity (Page 547)." However, it is not clearly described how these results are transmitted to these facilities. As your service expands in the future, you will be collecting and reporting greater amounts of data. Please explain how these data will be managed and coordinated between your laboratories and blood establishment facilities.*

Response: In the amendment received December 14, 2016 in response to FDA Question 36, the applicant stated that reports are sent manually by email in PDF format or as .csv file via secure FTP. The response is acceptable.

Comments: The response is acceptable. Resolved.

2/17/2017: The following are IR Questions not directly tied to previous questions, but arose during the review in progress or were originally-identified deficiencies that were not sent.

9. **FDA Question 14:** *In your original submission, in the Software Description document (Attachment 4-5-3 Imugen (b) (4) software description) on the second page, you stated that a version of (b) (4) will be compiled for commercial release which eliminates the Repository study option. Please provide the following:*
- a. *Describe the software architecture to convey the magnitude of this change; for example, is the Repository study option selected with a compile flag or is a more invasive method*

required to remove this functionality?

- b. Provide the test plan and test results illustrating that this recompile does not affect the functionality of the commercial release.*
- c. Confirm that this will be the only change to the software between the version used to perform the testing thus far, and the final commercial version. Update and provide your revision history documentation to reflect this and any other changes made since 8/28/2013.*

Response: In the Amendment received March 23, 2017 in response to FDA Question 14, the applicant stated that the (b) (4) software will no longer be compiled for commercial release. The software will only be used in-house. Corrections described in the response have been made resulting in software version “Build 1.0.5.5” which is described in the updated version documentation Revision History (IT-CSV-PDF-24). This is acceptable. However, the applicant is requested to ensure all design documentation is updated to reflect the final version.

Comments: The following was sent to the applicant on April 14, 2017 as new FDA Question 5, and included in the Complete Response letter sent June 13, 2017 as FDA Question 5 (but numbered as FDA Question 10):

Documentation package for Build 1.0.5.5: In the NAT Amendment received March 23, 2017 in response to FDA Question 14, you stated that the (b) (4) software will no longer be compiled for commercial release, but that the final version will be Build 1.0.5.5. Please review the documentation provided, and ensure that all design documentation including appropriate verification and validation testing corresponding to version Build 1.0.5.5 has been provided.

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 10 on PDF page 24, the applicant provided a table of updated design control documentation for Build 1.0.5.5, and referred to Attachment 13.3, which contains a table of a complete list of design documentation sent to FDA and which documents are obsolete. This is acceptable.

Comments: The response is acceptable. Resolved.

- 10. FDA Question 15: In your original submission in the document “Life Cycle Development Plan” (Attachment 4-5-8 Imugen (b) (4) Life Cycle Development), you stated on the first page that “[a]ll of the functions of the software, (i.e., the functions described in Section 5.0) were tested. All of the variations of the user inputs were also tested to detect unexpected conditions.” In your NAT Amendment response received December 14, 2016 in response to FDA Question #33 (and in your AFIA Amendment response received December 13, 2016 in response to FDA Question #38) you provided an updated traceability matrix. From the*

traceability information provided, it is not clear that comprehensive testing involving unexpected conditions was performed. Much of the testing appears to be testing to verify normal operation and does not explicitly specify test steps related to unexpected conditions or the corresponding identified risks. Note that necessary testing at the unit, integration and system level is often different and more comprehensive than qualification testing.

- a. Please provide testing documentation that supports this claim.*
- b. Please update your traceability matrix and testing documentation to explicitly include testing of the mitigations you identified in your risk analyses documents, including testing of the mitigations related to labeling and information for safety. References to testing of risk control measures can also be included in your risk documentation if this is easier. This is necessary to review how you determined that your mitigations appropriately reduce the risk to acceptable levels.*

Response: In the Amendment received March 23, 2017 in response to FDA Question 15, the applicant stated that two additional risks (and corresponding testing) were added to address unexpected conditions. The applicant did not provide convincing evidence to support that all unexpected conditions were identified and tested.

Comments: The following was sent to the applicant on April 14, 2017 as new FDA Question 3, and included in the Complete Response letter sent June 13, 2017 as FDA Question 8:

User interface error checking: In the NAT Amendment received March 23, 2017 in response to FDA Question 15, you stated that two additional risks were added, but it is not clear if this represents all unexpected conditions. Two conditions were included: R26b “Software must protect against import of corrupt or incomplete source file” and R26c “Software must not allow input of invalid result values.” Testing for R26b does not describe what was tested and why; it just illustrates that an uncharacterized file was rejected on import. Testing for R26c is limited to error checking on the IFA Slide screen. R29 describes software error detection functionality but the referenced testing in the traceability matrix (Attachment_15.2-IT-CSV-IMD14-16-TM&DocDetails.pdf) refers to IT-CSV-IMD14-07-OPQb, 6.8.11, #11, that does not appear to test or detect error conditions.

- a. Please provide a summary description of all user interface requirements and the types of error checking that is performed to identify problems with data interactions with the user via keyboard, barcode scanning, etc., and list the corresponding testing used to ensure proper functionality of the system. Please do not refer to entire design documents, but develop a direct response to this question. This is necessary to assess how the system responds to unexpected conditions and assess the scope of the error checking of the system.*

- b. *Please provide the corresponding design control documentation for the user interface requirements and error checking in (a).*

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 8 on PDF page 17, the applicant provided a table of modules, the user interface components, and a summary of the error checking. (a) The table on page 19 includes the software requirements specifications and a summary of the associated testing. Negative testing (boundary testing) references were provided. The applicant also described the differences between IT-(b) (4)-SPT-14 and IT-(b) (4)-SPT-15 and clarified why they appear to represent the same testing. (b) Document IDs and descriptions were provided.

The following was emailed to the applicant on November 9, 2017 as new FDA Question 2:

In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 8 on PDF page 17, you discussed requirements for error checking. FDA Question 8 stated that R29 describes software error detection functionality but the referenced testing does not appear to test or detect error conditions and no descriptive information was provided. Please clarify the purpose of this test and how it ensures that the requirement was adequately met.

Response: In the amendment (001_Response to IR Received 9Nov2017_NAT.pdf) received November 20, 2017 in response to FDA Question 2, the applicant stated that “*this requirement addresses the ability to identify altered records through the analysis of audit table queries and is not intended to address software error detection functionality.*” The requirement itself is poorly-written and the associated testing provided are not sufficient to determine if the requirement was adequately met. However, the topic is audit functionality and not (b) (4) functionality, so we will not challenge the applicant’s assertion “*that the requirement was adequately met.*”

Comments: The response is acceptable. Resolved.

11. **FDA Question 22:** *In your original submission in the NAT Design Risk Assessment document (Attachment 4-9-2-5 LAB-DSGN-11) in the risk table on page 31, you included an unnumbered risk, “Sample IDs and results are delinked, and false positive or false negative results are reported.” You stated that the mitigation includes “[a]greements with customers describe the use of barcode labels for samples.” Please describe the technical requirements that must be identified and met for these agreements with customers. Identify how these requirements are tested to ensure sample IDs and results are not delinked and how this adequately reduces the risk to ‘Low.’*

Response: In the Amendment received March 23, 2017 in response to FDA Question 22, the applicant provided an updated NAT risk assessment document (Attachment_22.1-LAB-

DSGN-11.xlsm) where hazards and requirements are correctly identified. New mitigations are included that do not require an agreement with the customer.

Comments: The response is acceptable. Resolved.

12. FDA Question 23: *In your NAT Amendment response received December 14, 2016 in response to FDA Question 32 you provided a Software Design Specification. On page 21 in section 3.3 you described use of the (b) (4) Software for creating a sample setup template and for exporting PCR results. This appears to correspond to requirements R27 and R28 on page 7 of the Software Requirements Specification in Attachment 29.2 and to the trace on page 8 of the updated Traceability Matrix in Appendix 29.3. Reference to creating and reading PCR slides appears in your original submission on page 604 in the QA scripts (e.g., “069_Attachment 4-5-8-1 (b) (4) QA Script for January 11 2013.pdf”) where templates are imported, selected, and then results are imported.*

- a. Please describe the content and format of the imported data files and any error checking performed to ensure that the import was successful and that the appropriate template and results are matched. This information should be explicitly captured in your requirements and/or specifications documents (or provided separately with explicit traceable references), with traceability to testing captured in your traceability documentation. Please update and provide the relevant documentation accordingly. It appears that document LAB-SFW-1 might be relevant to this discussion.*
- b. The V&V Test Cases only illustrated import of a valid file. Please provide testing to illustrate that the software is able to perform correctly when challenged with invalid or out of range data. This is necessary to ensure that the system is robust enough to protect against potentially corrupted incoming information from external uncontrolled sources.*

Response: In the Amendment received March 23, 2017 in response to FDA Question 23, the applicant created two new risks related to error checking and imported data files, performed corresponding testing, and updated the relevant design control documents, FMEA Risk Analysis (Attachment 15.1, IT-CSV-PDF-41), Traceability Matrix, (Attachment 15.2, IT-CSV-IMD14-16-TM) and SRS (Attachment 15.3, IT-CSV-IMD14-13-SRS). However, the applicant did not answer the posed questions. The interface with the (b) (4) instrument should be appropriately tested but the only documentation provided was a script with undefined inputs, making it impossible to know what was tested and if the testing was comprehensive.

Comments: The following was sent to the applicant on April 14, 2017 as new FDA Question 4, and included in the Complete Response letter sent June 13, 2017 as FDA Question 4 (but numbered as FDA Question 9):

PCR device interface verification: *In the NAT Amendment received March 23, 2017 in response to FDA Question 23, you reported two new risks related to error checking and*

imported data files and provided relevant design control documents. However, you did not respond to the question. We could not identify explicit information about the file format or interface with the (b) (4) instrument (R27 and R28). We could not confirm that the interface was appropriately tested because the only documentation for R26b provided was a script 6.8.3 (IT-CSV-IMD14-07-OPQc) with undefined inputs. Please respond to the original questions (a) regarding content and format of the imported data files, and (b) comprehensive testing of the system to ensure that the interface performs as intended.

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 9 on PDF page 23, the applicant included the missing information. The applicant clarified that there is no direct interface between (b) (4) and the (b) (4), and that results files and template files are manually selected and imported into (b) (4) by the operator. New testing was developed and performed (035_Attachment-8.3_IT(b) (4)-SPT-11& Doc Details.pdf) showing import of valid files and invalid files (including an attempted import of the Gettysburg Address to represent invalid file contents). The applicant also updated R59 to remove an inconsistency about the database file size and performed new testing in document. This is acceptable.

Comments: The response is acceptable. Resolved.

The following question was generated in response to information provided in the May 23, 2017 communication to FDA, and included in the Complete Response letter sent June 13, 2017 as FDA Question 13.

13. FDA Question 13: *In the (b) (4) status update received May 23, 2017 in response to FDA Question 1(a), you provided (b) (4) infrastructure details (b) (4) Infrastructure Details.docx).*

- a. *The (b) (4) database server appears to be running on an unsupported operating system, Windows (b) (4). As of July 14, 2015, Microsoft no longer provides automatic fixes, updates or security updates for this product to protect against harmful viruses, spyware and other malicious software. Your Information Technology Security Policy (Attachment_20.2-IT-SEC-POL-01&DocDetails.pdf) does not provide a process for supporting an operating system when patches are no longer available. Please provide your plan for migrating to a supported operating system. If you do not intend to upgrade, please discuss the additional security risks, how you will identify vulnerabilities and manage the risks of this increased exposure.*
- b. *Please identify the cybersecurity product(s), including version number(s), running on each of the servers and computers identified in the (b) (4) specific infrastructure. Your Information Technology Security Policy (Attachment_20.2-IT-SEC-POL-01&DocDetails.pdf) references two generic product lines but does not indicate how the individual systems are protected.*

Response: In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 13 on PDF page 34, the applicant explained that the migration from Windows Server (b) (4) to Windows Server (b) (4) is complete.

(a) The test protocol, test plan and verification reports were provided. The applicant stated all shortcuts to the prior version of (b) (4) were removed, and that all design control documentation was updated to remove references to Windows Server (b) (4). This is adequate, except that references to Windows Server (b) (4) still exist, and should be removed to avoid confusion. See the comment below.

(b) The applicant stated that “[i]n order not to compromise the security of our system and in accordance with IT-SEC-POL-1, “Information Technology Security Policy”, we are not permitted to provide cybersecurity software versions in written communications.” Further, the applicant stated that the information can be provided during the FDA pre-licensure inspection. Nothing in the applicant’s security policy references software versions in written communications. The document only reference to a list “restricted applications” that are maintained by IT and periodically reviewed, and no criteria or definition is provided for what a restricted application is. The applicant should respond to the question.

Comments: The following was emailed to the applicant on November 9, 2017 as new FDA Question 3:

In the complete response (001_BL125588-NAT Complete Response.pdf) received October 10, 2017 in the response to FDA Question 13 on PDF page 34, you stated that the migration from Windows Server (b) (4) to Windows Server (b) (4) is complete. Please address the following:

- a. *In part (a), you provided the (b) (4) DB Migration Verification test protocol document (051_Attachment-13.4_IT-(b) (4)-SPT-30& Doc Details.pdf) describing performance of the migration testing but did not provide the results of these tests cases. Only a summary test report was provided (052_Attachment-13.6_IT(b) (4) SPT-31& Doc Details.pdf). Please provide the document containing the results of the test scripts and protocol. This is necessary to confirm completion of the migration testing.*
- b. *In part (a), you stated that all references to Windows Server (b) (4) have been removed. Please note that at least one document still references Windows Server (b) (4) and should be updated: (b) (4) Software System Test Plan (024_Attachment-6.4_IT-(b) (4)-1 & Doc Details.pdf). Please check to ensure all documents are correctly updated.*

- c. *In part (b), you stated that according to your security policy, IT-SEC-POL-1 (Attachment_20.2-IT-SEC-POL-01&DocDetails.pdf) “we are not permitted to provide cybersecurity software versions in written communications.” We are unable to identify this restriction in your security policy. Please provide this information and clarify the concerns below, as these are necessary to complete the review of your submission. Stating that (b) (4) software and (b) (4) are implemented on the network” with no further details is not sufficient to evaluate that the vulnerable components of your system are adequately protected, or provide confirmation that the software is running on all computers and servers in the system. If you are not using the latest version of the referenced programs, please provide your assessment that the differences between the version used and the latest version do not adversely impact your system. If you continue to have concerns about providing this information, please submit it via DCC or send an email to SecureEmail@fda.hhs.gov and we will assist you in determining the type of secure communications to establish so that this information can be provided to continue this review.*

Response: In the amendment (001_Response to IR Received 9Nov2017_NAT.pdf) received November 20, 2017 in response to FDA Question 3, the applicant provided the following:

- (a) The verification was inadvertently omitted, and has been provided. It is adequate.
(b) The applicant clarified their original statement to indicate that appropriate references will be maintained; for example, references within the migration plan itself. This is adequate.
(c) The versions of (b) (4) were provided, and the applicant stated that versions are updated automatically as per policy. At the time this response was prepared by the applicant, both (b) (4) was actually shipping later versions of software.

The following should be conveyed to the applicant:

In the amendment (001_Response to IR Received 9Nov2017_NAT.pdf) received November 20, 2017 in response to FDA Question 3, you provided the versions of cybersecurity programs in use and stated that these are the latest version released and that you adhere to your policy of receiving automatic updates. Please note that at the time your response was prepared, both programs were currently advertised as having later versions of software than you provided. You should ensure that your mechanism for receiving automatic updates is working correctly. No further response is required.

Comments: The response is acceptable. Resolved.

8 Appendix 2: Device Description Details

Description of system equipment appears on page 3 in the document “MASTER VALIDATION PLAN NAT controls.docx” and reproduced below:

Equipment (Asset#/Serial#)	Manufacturer	Procedure	Calibration/Certification
(b) (4)	(b) (4)	LAB-MOL-LT-2	Temperature, Volume
		LAB-IQC-115	NSF#49
		LAB-IQC-66	Optics, Temperature
		LAB-IQC-43	Volume
		LAB-IQC-25 LAB-IQC-117	Temperature
		LAB-IQC-13 LAB-IQC-117	Temperature

(b) (4) Document “025 Attachment 4-2-3-21 LAB-MOL-LT-2.pdf” describes use of the (b) (4) for the Extraction Protocol: “[t]he (b) (4) provides fully automated nucleic acid purification from human whole blood and body fluids utilizing (b) (4) technology.” The document references procedures for use and maintenance of the instrument, including the necessary training required to perform the extraction. The procedure includes photographs of the instrument case and screen from power-up through all steps of the extraction and power down.

(b) (4): Used to perform the PCR process and provide results to the (b) (4) software.

Network Diagram: The following hardware network diagram was produced to illustrate the components of the system, the boundaries of the system, and the various operating systems and data flows. (021_Attachment-6.1_IT-CSV-IMD14-15-AD &Doc Details.pdf)

