November 15, 2016

Mr. Jerald G. Head
Senior Vice President, Regulatory Affairs
GE Hitachi Nuclear Energy
3901 Castle Hayne Road MC A-18
Wilmington, NC 28401

SUBJECT: THE GE HITACHI NUCLEAR ENERGY ADVANCED BOILING WATER REACTOR AIRCRAFT IMPACT ASSESSMENT INSPECTION, NUCLEAR REGULATORY COMMISSION INSPECTION REPORT NO. 05200045/2016-201

Dear Mr. Head:

From September 12, 2016, through September 16, 2016, the U.S. Nuclear Regulatory Commission (NRC) conducted an inspection of the GE Hitachi Nuclear Energy (GEH) Aircraft Impact Assessment (AIA) related to activities conducted in support of your application to renew the Advanced Boiling Water Reactor design certification. The NRC staff performed this inspection at the GEH Nuclear Energy office located in Wilmington, NC. The purpose of the inspection was to assess GEH's compliance with the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.150, "Aircraft impact assessment." The enclosed report presents the results of this inspection.

Based on the inspection samples, the NRC inspection team determined that a Severity Level 4 violation of NRC requirements occurred. The violation was evaluated in accordance with the enforcement policy. The violation is cited in the enclosed Notice of Violation (Notice), and the circumstances surrounding them are described in detail in the subject inspection report. The violation cites that GEH failed to fully: (1) identify and incorporate into the design those design features and functional capabilities to show the reactor core remains cool and spent fuel pool integrity is maintained; and (2) use realistic analyses in certain aspects of its AIA to show spent fuel pool integrity is maintained. With the exception of the violation identified in the Notice, the NRC inspection team concluded that the portions of the GEH Advanced Boiling Water Reactor AIA reviewed comply with the applicable requirements of 10 CFR 50.150, "Aircraft impact assessment."

You are required to respond to this letter and should follow the instructions specified in the enclosed Notice when preparing your response. The NRC will use your response, in part, to determine whether enforcement action is necessary to ensure compliance with regulatory requirements.

It is important to note that the NRC inspection team performed a limited review of the AIA. Many of the deficiencies identified may also affect other portions of the AIA that the NRC inspection team did not review. Therefore, GEH should extend its review, where applicable, beyond the

specific examples identified by the inspection team and apply corrective actions as appropriate. In its response to this violation, GEH should document the areas for which it extended its review beyond the specific examples of the deficiencies identified by the inspection team, the extent of its review, the additional findings, and the corrective actions implemented.

In accordance with 10 CFR 2.390 of the NRC's "Public inspections, exemptions, requests for withholding," of the NRC's "Rules of Practice," a copy of this letter, its enclosures, and your response will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's Agencywide Document Access and Management System (ADAMS), accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. To the extent possible, your response, if applicable, should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the public without redaction. If personal privacy or proprietary information is necessary to provide an acceptable response, then please provide a bracketed copy of your response that identifies the information that should be protected and a redacted copy of your response that deletes such information. If you request that such material is withheld from public disclosure, you must specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If Safeguards Information is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21, "Protection of Safeguards Information: Performance Requirements."

Sincerely,

/RA/

Terry W. Jackson, Chief
Quality Assurance Vendor Inspection Branch-1
Division of Construction Inspection
and Operational Programs
Office of New Reactors

Docket No.: 05200045

Enclosures:
1. Notice of Violation
2. Inspection Report No. 05200045/2016-201
   and Attachment

specific examples identified by the inspection team and apply corrective actions as appropriate. In its response to this violation, GEH should document the areas for which it extended its review beyond the specific examples of the deficiencies identified by the inspection team, the extent of its review, the additional findings, and the corrective actions implemented.

In accordance with 10 CFR 2.390 of the NRC's "Public inspections, exemptions, requests for withholding," of the NRC's "Rules of Practice," a copy of this letter, its enclosures, and your response will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's Agencywide Document Access and Management System (ADAMS), accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. To the extent possible, your response, if applicable, should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the public without redaction. If personal privacy or proprietary information is necessary to provide an acceptable response, then please provide a bracketed copy of your response that identifies the information that should be protected and a redacted copy of your response that deletes such information. If you request that such material is withheld from public disclosure, you must specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If Safeguards Information is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21, "Protection of Safeguards Information: Performance Requirements."

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ADAMS Accession No.: ML16285A219 *concurred via email NRO-002

OFC	NRO/DSRA/SPRA	NRO/DSRA/SPSB	NRO/DSRA/SPSB	NRO/DEIA/SEB	NRO/DEIA/SEB
NAME	MCaruso*	DAndrukat*	RNolan	GWang*	AIstar*
DATE	10/20/16	10/18/16	10/18/16*	10/19/16	10/19/16
OFC	NRO/DCIP/QVIB-1	NRO/DNRL/LB3/BC	NRO/DEIA/SEB/BC	NRO/DSRA/SPRA/BC	NRO/DSRA/SPSB/BC
NAME	SSmith*	MDudek*	SSamaddar*	LMrowca*	ADias*
DATE	11/14/16	10/25/16	10/25/16	11/3/16	11/02/16
OFC	NSIR/DSO/ISB	OGC	NRO/DCIP/QVIB2	NRO/DCIP/QVIB-1/BC	
NAME	RNorman*	MSpencer (MMarsh for)*	ABelen-Ojeda	TJackson	
DATE	10/27/2016	11/8/16	11/14/16	11/15/16	

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Letter to Jerald G. Head from Terry W. Jackson dated November 15, 2016

SUBJECT: THE GE HITACHI NUCLEAR ENERGY ADVANCED BOILING WATER REACTOR AIRCRAFT IMPACT ASSESSMENT INSPECTION, NUCLEAR REGULATORY COMMISSION INSPECTION REPORT NO. 05200045/2016-201

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NOTICE OF VIOLATION

GE Hitachi Nuclear Energy (GEH) Docket No.: 05200045
Wilmington, NC Inspection Report No.: 2016-201

During a U.S. Nuclear Regulatory Commission (NRC) inspection of the GE Hitachi Nuclear Energy (GEH) advanced boiling water reactor (ABWR) aircraft impact assessment (AIA) conducted in Wilmington, NC, on September 12-16, 2016; one violation of NRC requirements was identified. In accordance with the NRC Enforcement Policy, the violation is listed below:

A. Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.150, "Aircraft impact assessment," Paragraph (a)(1) requires that each applicant listed in 10 CFR 50.150(a)(3) shall perform a design-specific assessment of the effects on the facility of the impact of a large, commercial aircraft. Using realistic analyses, the applicant shall identify and incorporate into the design those design features and functional capabilities to show that, with reduced use of operator actions:

   (i) the reactor core remains cooled, or the containment remains intact; and
   (ii) spent fuel cooling or spent fuel pool integrity is maintained.

   GEH chose to meet 10 CFR 50.150 by showing that the reactor core remains cooled and spent fuel pool integrity is maintained. But contrary to 10 CFR 50.150, as of September 16, 2016, GEH failed to identify and incorporate into the design control document (DCD) those design features and functional capabilities credited in the AIA to show the reactor core remains cool and spent fuel pool integrity is maintained. Specifically, the following design features and functional capabilities that were credited to stop damage footprints in the AIA were not identified and/or accurately incorporated in the DCD:

   - Section 3H.6, "Summary of Key Structural Design Features," stated that walls will be strengthened to limit physical damage as described in NEDE-33875P. However, NEDE-33875P failed to identify the wall, wall location, elevation, and an exterior wall designation used to limit physical damage in the assessment;

   - Location of a water tight door and 3-hour, 5-pounds per square inch differential (psid) fire barrier on Elevation 3F; and

   - Fixed locations of buildings needed to prevent damage from an aircraft impact.

   In addition, GEH failed to use realistic analyses in certain aspects of its AIA. Specifically, GEH did not provide enough information to demonstrate that the spent fuel pool (SFP) liner has adequate resolution of the localized plastic deformation to ensure that the structural integrity of SFP is maintained.

   These examples have been identified as Violation 05200045/2016-201-01.

   This is a Severity Level IV Violation (Section 6.5).

Pursuant to the provisions of 10 CFR 2.201, “Notice of Violation,” GEH is hereby required to submit a written statement or explanation to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, DC 20555-0001, with a copy to the Chief, Quality Assurance Vendor Inspection Branch-1, Division of Construction Inspection and Operational Programs, Office of New Reactors, within 30 days of the date of the letter transmitting this Notice of Violation. This reply should be clearly marked as a “Reply to a Notice of Violation” and should include: (1) the reason for the violation, or, if contested, the basis for disputing the violation or severity level, (2) the corrective steps that have been taken and the results achieved, (3) the corrective steps that will be taken to avoid further violations, and (4) the date when full compliance will be achieved. Your response may reference or include previous docketed correspondence, if the correspondence adequately addresses the required response. Where good cause is shown, the NRC will consider extending the response time.

Because your response will be made available electronically for public inspection in the NRC Public Document Room or from the NRC’s Agencywide Documents Access and Management System, accessible at http://www.nrc.gov/reading-rm/adams.html, to the extent possible, it should not include any personal privacy, proprietary, or Safeguards Information so that it can be made available to the public without redaction. If personal privacy or proprietary information is necessary to provide an acceptable response, then please provide a bracketed copy of your response that identifies the information that should be protected and a redacted copy of your response that deletes such information. If you request withholding of such material, you must specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim of withholding (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If Safeguards Information is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21, “Protection of Safeguards Information: Performance Requirements.”

Dated this the 15th day of November 2016

U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NEW REACTORS
DIVISION OF CONSTRUCTION INSPECTION AND OPERATIONAL PROGRAMS
VENDOR INSPECTION REPORT

Docket No.:	05200045
Report No.:	05200045/2016201
Inspection Location:	3901 Castle Hayne Rd. Wilmington, NC 28401
Contact:	Patricia Campbell GE Hitachi Nuclear Energy (GEH) Washington Regulatory Affairs patriciaL.campbell@ge.com
Nuclear Industry Activities:	GEH has completed their aircraft impact assessment of the advanced boiling water reactor design certification to comply with the U.S. Nuclear Regulatory Commission requirements in Title 10 of the *Code of Federal Regulations* Section 50.150, "Aircraft Impact Assessment." This inspection is for the design certification renewal application submitted to the NRC by GEH on December 7, 2010.
Inspection Dates:	September 12-16, 2016
Inspectors:	Stacy Smith, Team Leader, NRO/DCIP/QVIB-1 Mark Caruso, NRO/DSRA/SPRA Dennis Andrukat, NRO/DSRA/SPSB Ryan Nolan, NRO/DSRA/SPSB George Wang, NRO/DEIA/SEB Ata Istar, NRO/DEIA/SEB Dr. Chris Jones, Sandia National Laboratory Dr. Alexander L. Brown, Sandia National Laboratory
Approved by:	Terry W. Jackson, Chief Quality Assurance Vendor Inspection Branch-1 Division of Construction Inspection and Operational Programs Office of New Reactors

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) conducted this inspection to verify that GE Hitachi Nuclear Energy (GEH) had implemented the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.150, "Aircraft Impact Assessment," and performed a design-specific assessment [1] of the effects on the facility of the impact of a large commercial aircraft.

The NRC conducted the inspection of GEH in Wilmington, NC, September 12-16, 2016.

The following served as the bases for the NRC inspection:

- 10 CFR 50.150

During this inspection, the NRC inspection team implemented Inspection Procedure (IP) 37804, "Aircraft Impact Assessment," dated February 9, 2012.

This inspection was performed to verify that GEH's aircraft impact assessment (AIA) of the advanced boiling water reactor (ABWR) design complies with the requirements of 10 CFR 50.150. Revision 8 of NEI 07-13, "Methodology for Performing Aircraft Impact Assessments for New Plant Designs," dated April 2011, has been endorsed by the NRC in Regulatory Guide (RG) 1.217, "Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts," as one means of performing an AIA acceptable to the NRC. GEH utilized NEI 07-13, Revision 8, with no exceptions, to perform their AIA.

For the implementation of this inspection, the NRC team used Revision 6 of GEH's design control document (DCD) (ADAMS Accession No. ML16214A015) and, in addition, the DCD markups to Revision 6 documented in MFN-16-027 letter, Revision 1, dated September 14, 2016.

The NRC inspection team concluded that, with the exception of the violation cited in the Notice, the portions of the GEH ABWR AIA reviewed by the NRC inspection team comply with the applicable requirements of 10 CFR 50.150. The results of the inspection are summarized below.

Systems-Loss Assessment

The NRC inspection team concluded the systems-loss assessment performed by GEH for the AIA is consistent with the regulatory requirements of 10 CFR 50.150.

Fire Damage Assessment

The NRC inspection team found that with the exception of Violation 05200045/2016-201-01, the fire damage assessment performed by GEH for the AIA is consistent with the regulatory requirements of 10 CFR 50.150.

[1] By a ''design-specific'' assessment, the NRC means that the impact assessment must address the specific design of the facility that is either the subject of a construction permit, operating license, standard design certification, standard design approval, combined license, or manufacturing license application (see 74 FR 28129; June 12, 2009).

Structural Damage Assessment

The NRC inspection team found that with the exception of the three examples of Violation 05200045/2016-201-01, the structural damage assessment performed by GEH for the AIA is consistent with the regulatory requirements of 10 CFR 50.150.

Documentation and Quality Assessment

The NRC inspection team concluded that with the exception of Violation 05200045/2016-201-01, documented in Sections 2.b.1, 3.b.1, and 3.b.2 of this inspection report, the documentation and quality assessment performed by GEH for the AIA is acceptable.

REPORT DETAILS

1. Systems-Loss Assessment

   a. Inspection Scope

      The NRC inspection team reviewed the following activities for GEH's ABWR AIA systems-loss assessment:

      - Verification of the location of those structures, systems, and components (SSC) that provide core cooling or containment isolation, and spent fuel pool (SFP) integrity to determine the potential for damage by aircraft impact;

      - Verification that those SSCs would be capable of performing their intended function given the established structural, shock, and fire damage footprints and the rule sets and assumptions provided in NEI 07-13;

      - Verification that GEH addressed accident initiators, such as a breach of the reactor coolant system (RCS) or the failure of the reactor to trip, that could result from damage caused by an aircraft impact; and

      - Verification that success paths for core cooling exist.

   b. Observations and Findings

      b.1 Determination of the location of credited SSCs

      The NRC inspection team reviewed GEH's selection of SSCs needed to prevent fuel damage in the core and the documented spatial configuration of those SSCs. Since GEH chose to meet the aircraft impact assessment rule by maintaining core cooling and SFP integrity, SSCs needed to maintain containment intact and to provide for SFP cooling were not reviewed.

      The NRC inspection team compared the descriptions of SSCs in the assessment report to those in the design control document (DCD) and the probabilistic risk analysis (PRA) in the ABWR supplemental safety analysis report. The NRC inspection team confirmed that the scope of SSCs treated in the assessment was complete and consistent with those needed to satisfy the core cooling success criteria in the PRA. The inspection team used equipment location data and drawings in Section 9A, "Fire Hazard Analysis," of the DCD to confirm that the locations of equipment documented in the assessment report were accurate.

      The NRC inspection team verified the most current documentation was used to develop and identify spatial information (e.g., internal events PRA, internal flooding analysis, internal fire analysis and building layout diagrams).

b.2 Determination of the state of SSCs in the aircraft impact scenarios

The NRC inspection team reviewed the AIA to evaluate whether GEH correctly applied the rules and assumptions given in NEI 07-13 for the loss of SSCs. Specifically, the team selected a sample of SSCs that GEH identified as remaining functional in one or more scenarios and verified the basis used to conclude these SSCs would survive conditions created by an aircraft impact were consistent with the rule sets and assumptions given in NEI 07-13.

The NRC inspection team reviewed those portions of GEH's assessment report that discussed the approach used to identify which SSCs would remain capable of performing their intended function following an aircraft impact. The inspection team determined the emergency core cooling system (ECCS) and its support systems include three independent and redundant divisions that are physically separated within the reactor building. The equipment in each division is capable of maintaining core cooling. The instrumentation used to actuate and control the ECCS is also separated by division. The inspection team determined that GEH considered the potential effect of structural, shock, and fire damage on core cooling equipment. In some instances damage occurred to a division containing ECCS equipment credited for supporting core cooling. In these cases GEH confirmed that redundant equipment providing core cooling was not located within the same damage area and, therefore, was protected and capable of providing core cooling. The inspection team verified that GEH's approach was consistent with the approach described in NEI 07-13.

b.3 Determination of Accident Conditions

The NRC inspection team verified that GEH used appropriate assumptions and scenarios to determine accident conditions. These assumptions were consistent with NEI 07-13 and include:

- GEH's success criteria and the scenario analysis that addresses initial plant states of 100 percent power and cold shutdown;
- The analysis takes no credit for the availability of offsite power;
- The analysis assumes, as part of its shutdown cooling scenarios, the reactor vessel is vented, the water level is at or near the reactor vessel head flange, and the reactor has been shut down for a specified time;
- The consideration of the possibility of an anticipated transient without scram (ATWS);
- GEH considered the influence of containment status on the operability of other equipment (e.g., pumps that draw suction water from the suppression pool); and,
- GEH searched for instances in which a containment bypass loss of coolant accident (LOCA) may occur.

Specifically, the NRC inspection team reviewed GEH's treatment of the following potential accident conditions:

LOCA Inside Containment

The NRC inspection team reviewed GEH's assessment of a LOCA inside the containment to determine if the containment is adequately protected such that it could not be impacted by an aircraft. The NRC inspection team determined the assessment adequately demonstrated that neither shock damage to the containment nor structural damage inside the containment would occur and, as such, verified that a LOCA inside the containment would not occur.

LOCA Outside Containment

The NRC inspection team reviewed GEH's assessment of a LOCA outside containment to determine if piping outside of primary containment that is connected to the reactor coolant pressure boundary, above grade level, is protected from structural damage. The assessment concludes that strengthened exterior walls and interior walls and barriers of the reactor building prevent physical damage to rooms containing containment penetration valves. The inspection team used elevation and data provided in Table 6.2-8, "Primary Containment Penetration List," of the DCD, as well as plan and elevation drawings of the reactor building to confirm that GEH's assessment effectively determined the applicable piping was adequately protected from structural damage.

ATWS

The NRC inspection team reviewed the AIA to determine if GEH adequately assessed the potential for any damage scenarios that could affect the ability to scram the reactor. The inspection team considered potential structural damage to the hydraulic control units used to shutdown the reactor. The NRC inspection team reviewed drawings from the fire hazards analysis to confirm that the hydraulic control units are located below grade, outside all structural damage footprints, and verified that an ATWS was not a viable outcome from an aircraft impact.

Flooding

The NRC inspection team reviewed the AIA to determine if GEH adequately assessed the potential for flooding from a large water source as described in NEI 07-13. The assessment stated that the GEH-ABWR DCD layouts indicated there are no open loop cooling systems in the physical damage impact zones. Therefore, expansion of damage footprints due to flooding is not required. The NRC inspection team verified that potential flow paths for flooding were either located below grade and, therefore, not vulnerable to breach because of an aircraft impact, or were isolable at a remote location away from the reactor or control buildings.

Loss of Decay Heat Removal – Shutdown

The NRC inspection team reviewed the AIA to determine if GEH adequately assessed the potential for a loss of decay heat removal event when the reactor is shutdown. The NRC inspection team reviewed the assumptions used in the analysis and verified that they were consistent with guidance in NEI 07-13. Specifically, the reactor vessel is vented, water level is at or near the reactor vessel head flange, and the reactor has been shut down for a specified time. The NRC inspection team noted the DCD has administrative controls to ensure that, for shutdown conditions, residual heat removal (RHR) Train A and either RHR or high pressure core flooder for Trains B and C are not out of service for maintenance until the cavity is flooded and the spent fuel pool gates are open. These administrative controls ensure adequate water for core cooling would be available for at least 24 hours.

b.4 Identification of Success Paths

The NRC inspection team reviewed the AIA to determine if GEH had a success path for core cooling. The inspection team reviewed the PRA (GE Nuclear Energy Report No. 23A6100), which served as the basis for information documented in Chapter 19, "Response to Severe Accident Policy Statement," of the DCD, and verified that the normal decay heat removal methods identified by GEH were shown as success paths for avoiding core damage.

c. Conclusions

The NRC inspection team concluded the systems-loss assessment performed by GEH for the AIA is consistent with the regulatory requirements of 10 CFR 50.150.

2. Fire Damage Assessment

a. Inspection Scope

The NRC inspection team conducted the following fire damage assessment activities relating to GEH's AIA:

- Verification that the fire damage assessment identifies and incorporates the necessary design features and functional capabilities;
- Verification that the fire damage assessment is realistic and design-specific;
- Verification that the damage footprints include the effects from the spread of fire damage through existing connected compartments and through new compartment connections due to overpressure; and
- Verification SSCs determined to be damaged and are no longer credited.

b. Observations and Findings

b.1 Damage Footprint Assessment

The GEH AIA evaluated a total of 54 different impact scenarios throughout the reactor building in accordance with NEI 07-13. The NRC inspection team reviewed a sample of ten impact scenarios (Scenarios 6, 7, 14, 15, 16, 19, 27, 28, 29, 30) that included one or more of the following criteria: large fire damage footprints, fire damage footprints resulting in damage to three safety divisions, and fire damage footprints with impact strikes to Floors 1F, 2F, and 3F. The NRC inspection team reviewed the fire damage assessment contained in the Jensen-Hughes report and found the GEH ABWR fire damage footprints, as a result of the sampled aircraft impact scenarios, in general, consistent with the rules and assumptions given in NEI 07-13. The NRC inspection team also verified that the key design features used in the assessment for these impact scenarios were, in general, consistent with those features credited in GEH's DCD.

The NRC inspection team found examples within Impact Scenarios 27-30 where the fire damage footprint would significantly differ if using the docketed design. These discrepancies include wall thicknesses and fire door type, location, and robustness. Some of these features were used to separate divisions and fire areas. Specifically, the NRC inspection team identified that Impact Scenario 29 had fire damage footprints that did not reflect the design documented in the DCD. There were a number of incorrect fire damage footprints based on the incorrect location of a water tight door and 3-hour, 5-pounds per square inch differential (psid) fire barrier on Elevation 3F. The assessment utilized a 3-hour, 5-psid fire barrier (including water tight door) located in a different location than what is described in GEH's design via the MFN-16-027 letter.
10 CFR 50.150(a)(1) requires, in part, a design-specific assessment of the effects on the facility of the impact of a large, commercial aircraft. Using realistic analyses, the applicant shall identify and incorporate into the design those design features and functional capabilities to show that, with reduced use of operator actions: (i) the reactor core remains cooled, or the containment remains intact; and (ii) spent fuel cooling or spent fuel pool integrity is maintained. Contrary to this requirement, the NRC inspection team determined that a portion of the involved fire damage footprints did not include all of the required fire damage areas. GEH's failure to identify key design features credited in the ABWR AIA to stop fire damage is the first example of deficiencies contributing to Violation 05200045/2016-201-01. GEH opened Corrective Action Report 20448, dated September 14, 2016, to address this deficiency.

The NRC inspection team also reviewed several impact scenarios involving damage to all three safety divisions. Although all three safety divisions were damaged, the team found that for those impact scenarios sampled, at least one safety division did not incur damage to credited core cooling equipment (i.e., damage to the credited surviving division was only to fire areas not containing credited core cooling equipment).

b.2 Fire Damage Effects on SSCs

The NRC inspection team verified that GEH properly identified the SSCs within the fire damage footprint and correctly considered the identified SSCs as failing within 5 minutes of the start of the fire consistent with the guidance provided in NEI 07-13. Further review of damage to the SSCs was conducted and documented above in Section 1, "Systems-Loss Assessment."

c. Conclusions

The NRC inspection team found that with the exception of Violation 05200045/2016-201-01, the fire damage assessment performed by GEH for the AIA is consistent with the regulatory requirements of 10 CFR 50.150.

3. Structural Damage Assessment

a. Inspection Scope

The NRC inspection team verified the following elements of GEH's ABWR AIA structural damage assessment:

- Adequacy of information found in plant documentation including plant arrangement drawings displaying locations of major equipment, plant elevation drawings documenting the relative heights of various buildings,
- Civil-structural drawings that provide wall thicknesses and reinforcement details, and material specifications;
- General structural analysis considerations such as design inputs, analysis parameters and assumptions, computer codes, methods used for structural analyses and results to evaluate whether GEH adequately analyzed the effects of, and damage to structures resulting from, global and local aircraft impact loads;
- SFP impact analyses to evaluate whether GEH addressed the criteria in Section 2.5 of NEI 07-13; and,
- Structural damage footprint assessments to evaluate whether GEH adequately assessed the containment and other reinforced concrete buildings containing essential SSCs for maintaining reactor core cooling using the damage rule sets in Section 3.3 of NEI 07-13.

b. Observations and Findings

b.1 Structural Assessment Document Review

The NRC inspection team reviewed GEH's structural assessment design inputs including plant arrangement drawings, plant elevation drawings, civil-structural drawings, and material specifications. The inspection team verified the plant arrangement drawings display the locations of major equipment (e.g., trolley), and the plant elevation drawings identified the relative heights of various buildings with the exceptions identified below.

The NRC inspection team verified DCD material specifications, including the specification for concrete to have a compressive strength of 4,000 psi, were appropriately reflected in Reinforced Concrete Containment Vessel (RCCV) drawings. The NRC inspection team found that RCCV Drawing 24156-1U71-S5001, Revision 1, Note 2, indicated that concrete shall have a minimum compressive strength of 5,000 psi, which is a greater compressive strength than 4,000 psi in the DCD. Using an increased concrete strength for structures would improve the damage-footprint under potential

aircraft impact loads. Therefore, the NRC inspection team concludes that increasing the concrete strength was acceptable.

The NRC inspection team found that GEH's DCD and its incorporated reference failed to identify some key design features that were credited in the ABWR AIA to stop physical damage. NEI 07-13 Section 3.3.2, "Damage Rule Sets for Reinforced Concrete Buildings," states that physical damage is propagated into a structure until the total number of reinforced walls that meet specific criteria are reached. GEH identified the walls used to limit physical damage in Section 3H.6, "Summary of Key Structural Design Features" and referenced document NEDE-33875P. However, NEDE-33875P failed to identify a wall, wall location, wall elevation, and an exterior wall designation used to limit physical damage in the assessment. This deficiency includes features described above in Section 2.b.1, "Damage Footprint Assessment." As described in Section 2.b.1 of this report, 10 CFR 50.150(a)(1) requires, in part, identification and incorporation of those design features and functional capabilities to show that, either the reactor core remains cooled or the containment remains intact, and spent fuel cooling or spent fuel pool integrity is maintained. GEH's failure to adequately identify a wall, wall location, wall elevation, and an exterior wall credited for limiting physical damage in the assessment is the second example of deficiencies contributing to Violation 05200045/2016-201-01 that cites GEH for failure to identify and incorporate into the design control document (DCD) those design features and functional capabilities credited in the AIA to show the reactor core remains cool and spent fuel pool integrity is maintained as required by 10 CFR 50.150(a)(1). GEH opened Corrective Action Reports 21455 and 21456, both dated September 15, 2016, to address these deficiencies.

In addition, the NRC inspection team found the DCD did not adequately identify the fixed locations of buildings credited to prevent damage from an aircraft impact. Without identification of fixed locations of specific buildings, credit should not be taken for intervening structures in accordance with NEI 07-13, "Screening Based on Intervening Structures" to screen credible strike locations. Based on GEH's response to this violation, including any fixed locations of buildings credited as intervening structures to screen the control building, and consideration of corner strike scenarios, the NRC inspection team will determine if a realistic analysis needs to be performed to show that with reduced use of operator actions the reactor core remains cooled. GEH's failure to include the fixed locations of the buildings was determined to be a third example of deficiencies contributing to Violation 0500045/2016-201-01 that cites GEH for failure to identify and incorporate into the DCD those design features and functional capabilities credited in the AIA to show the reactor core remains cool and spent fuel pool integrity is maintained as required by 10 CFR 50.150(a)(1).

b.2 General Structural Analysis

The NRC inspection team verified that GEH used appropriate design inputs including the structural analysis parameters and assumptions, type of finite elements used in each analysis, material models considered, boundary conditions and extent of model, initial conditions, and time duration of the analysis. In addition, the NRC inspection team verified that GEH adequately documented and justified the structural design input for a sampling of analysis and adequately analyzed the effects of, and damage to structures resulting from, local and global loading arising from an aircraft impact.

The NRC inspection team verified that GEH properly modeled the reinforcing bars as sub-elements embedded within the concrete elements at the appropriate locations, and steel liners in the SFP as plate bending elements. However, the NRC inspection team was unable to find any finite element mesh refinement sensitivity analysis. GEH informed the inspection team that mesh refinement sensitivity analyses were not performed for the AIA. GEH's AIA report states the meshing design used in the analysis was based on past experience where sufficient mesh refinement for adequate distribution of forces is balanced against computer resources required when the airplane model is included in the analysis. The NRC inspection team determined that GEH did not evaluate the sensitivity of mesh design used in the analysis, which is considered the generally accepted practice for the given application. Specially, the NRC inspection team determined that GEH did not provide enough information to demonstrate the SFP liner has adequate resolution of the localized plastic deformation to ensure the structural integrity of SFP is maintained. More information is needed to evaluate if uncertainty in the results due to mesh sensitivity might change the findings or overall conclusions of the assessment, and specifically, that SFP integrity is maintained. The professionally accepted approach in these circumstances would have been to perform mesh refinement sensitivity analyses or adequately demonstrate the mesh used is acceptable under the circumstances. GEH's failure to follow professionally accepted approaches does not comply with the requirement to perform a realistic analysis as described in the final AIA rule (see 74 FR 28130; June 12, 2009). This is the fourth example of Violation 05200045/2016-201-01 that cites GEH for failure to use realistic analyses in certain aspects of its AIA, as required by 10 CFR 50.150(a)(1). This issue does not represent a safety concern because no designs of this type are currently under construction in the United States.

The NRC inspection team verified that all potential aircraft impact scenarios were considered in the structural analyses. The NRC inspection team reviewed a sample of the structural damage impact scenario analyses and verified that GEH properly applied the NRC-supplied forcing function and missile-target interaction to the appropriate structural damage impact scenarios. In addition, the NRC inspection team reviewed the assumptions used in the structural damage analyses and verified that GEH adequately documented the technical basis in the AIA for the assumptions used in the analyses.

The NRC inspection team reviewed a sample of structural damage analyses and verified that GEH used the correct failure criteria. As part of the review, the NRC inspection team verified the various material properties used in the structural analyses were developed precisely in accordance with the NEI 07-13 guidance. However, GEH did not take credit for the dynamic increase factors for concrete as allowed for in NEI 07-13. Instead, GEH captured the dynamic effects of rate stiffening and confinement, as well as computation of damage and failure. The NRC inspection team verified this treatment and considered it acceptable because it is more rigorous and accurate.

b.3 Containment Structure and SFP Specific Impact Assessment

The NRC inspection team reviewed the containment and SFP impact analyses to evaluate whether GEH met the sufficiency criteria in NEI 07-13, Section 2.5.

The NRC inspection team reviewed the structural damage assessment as it relates to local loading on the containment and SFP structure and verified that GEH conducted the following activities in accordance with NEI 07-13, Section 2.1:

- Documented and cross-checked the aircraft engine parameters used in the analysis against NRC-specified parameters.

- Properly applied the various local loading formulas referenced in NEI 07-13, Subsection 2.1.2, to arrive at the degree of local damage and the wall thickness required to prevent perforation of the target.

- Used the formulas cited in NEI 07-13 and approved by the NRC.

- The NRC inspection team reviewed the structural damage assessment as it relates to global loading effects on the containment and SFP structure. The inspection team verified that the following activities were conducted in accordance with NEI 07-13, Section 2.2:

- Documentation and use of the application of the force time-history analysis method and cross-checking it for its equivalency to the NRC-specified force time-history.

- Documentation of the application of the missile-target interaction analysis method and cross-checking it for its equivalency to the NRC-specified force-time history.

- The missile-target interaction analysis method reasonably captured the mass distribution of the missile when a “reverse-engineering” approach was used to determine the missile-target interaction from the force-time history.

- For the application of the force time-history analysis method, GEH properly used and adequately documented the NRC-specified spatial distribution of the impact force in the analyses.

The NRC inspection team reviewed a sample of documents for material characterization and failure criteria related to the structural damage assessment and verified that the following analysis activities were conducted in accordance with NEI 07-13, Section 2.3:

- Application of the ANACAP-U concrete constitutive model consisting of material properties and the equations used to model the nonlinear behavior of both steel and reinforced concrete materials in the analyses. The model parameters used are adequately documented and consistent with the material properties and equations documented in NEI 07-13, Section 2.3.

- Identification of the dynamic effects of rate stiffening and confinement, as well as computation of damage and failure instead of using the dynamic increase factors specified in NEI 07-13, Subsection 2.3.1, for the various materials used in the analyses.

- Application of the ductile failure strain limits specified in NEI 07-13, Subsection 2.3.2, for the various materials used in the analyses.

- The concrete structural failure criteria used in the analyses are appropriately documented and consistent with the criteria specified in NEI 07-13, Subsection 2.3.3.

- Application and documentation of the material models specified in NEI 07-13, Subsection 2.3.4.

- Application and documentation of the structural integrity failure criteria specified in NEI 07-13, Subsection 2.3.5.

The NRC inspection team reviewed the major assumptions applied to the containment and SFP related structural analyses and verified that the following activities were conducted in accordance with NEI 07-13, Section 2.4:

- Missile-target interaction analysis model properly assumed that the aircraft impact was perpendicular to the centerline of the containment.

- Missile-target interaction analysis model properly assumed takeoff weight such that the missile-target interaction model is equivalent to the NRC-specified force time-history.

- Containment regions containing critical penetrations received an appropriate level of special consideration.

- Spent fuel pool analyses properly assumed that both the engine and the aircraft fuselage strike was perpendicular to and at the mid-point of the spent fuel pool wall.

- Assessment of potential aircraft impact at other locations that could result in greater consequences.

- No credit was taken for fuel pool water inventory in its SFP analyses.

The NRC inspection team reviewed the sufficiency criteria applied to the SFP related structural analyses and verified GEH's conclusion, that integrity of the SFP was maintained, was consistent with the sufficiency criteria of NEI 07-13, Subsection 2.5.2, with the exception of the deficiency cited in Violation 05200045/2016-201-01 as described in Section 3.b.2, "General Structural Analysis."

b.4 Structural damage footprint assessment

The NRC inspection team reviewed the structural damage footprint analyses to evaluate whether or not the following items of interest related to the damage rule sets identified in NEI 07-13, Chapter 3, "Heat Removal Capability," have been met.

- Structures of concern that contain SSCs have been identified.

- A systematic evaluation of susceptible damage was conducted and adequately documented.

- Assumptions used to determine elevations of concern have been addressed and adequately documented.

- Each external face of each building exposed to a direct hit has been divided into two categories, containment structures and other reinforced concrete buildings, and each external face has been analyzed and adequately documented.

The NRC inspection team verified that the structural damage rule sets for containment structures were appropriately assessed consistent with the guidance in NEI 07-13, Subsection 3.3.1. In addition, the NRC inspection team verified that the structural damage rule sets for reinforced concrete buildings were appropriately assessed consistent with the guidance in NEI 07-13, Subsection 3.3.2. The NRC inspection team verified that the following activities were conducted in the analyses:

- Various impact points have been investigated and documented in order to define the damage footprint.

- Structural damage rule sets regarding perforations were appropriately developed.

- Shock damage was evaluated in the structural damage footprints and these evaluations have been adequately documented.

- The guidance in NEI 07-13, Table 3-3, was used to define the shock damage footprints and was adequately documented.

- Shock effects impacting seismic separation between buildings has been adequately assessed and documented.

c. Conclusions

The NRC inspection team found that with the exception of the three examples of Violation 05200045/2016-201-01, the structural damage assessment performed by GEH for the AIA is consistent with the regulatory requirements of 10 CFR 50.150.

4. AIA Documentation and Quality Assessment

a. Inspection Scope

The NRC inspection team verified the following activities for GEH's ABWR AIA quality assurance assessment:

- GEH adequately documented the assessment in a quality manner consistent with NEI 07-13, Section 5.1, and

- GEH adequately established standards and measures to establish the validity of the assessment and supporting calculations.

b. Observations and Findings

b.1 Documentation

During its review of the AIA documentation, the NRC inspection team determined that some of the information documented within the AIA was not described in the DCD. The violation related to the inconsistencies are discussed in Sections 2.b.1, 3.b.1, and 3.b.2 of the inspection report. In addition, the NRC team noted other minor deficiencies with the AIA, including mislabeling (with an asterisk) fire areas that contain critical equipment, shock damage tables in Appendix A that are inconsistent with footprints in Appendix B (scenarios 27-30), missing structural damage rooms (but with the correct fire areas credited), and some minor text editorial problems.

The NRC inspection team was unable to find civil-structural drawings to verify wall thicknesses and reinforcement details of the strengthened exterior and interior walls. The NRC inspection team determined the assessment accurately reflected the wording in the DCD, and therefore NRC requirements of a design-specific assessment were met. Notwithstanding, the NRC inspection team noted this observation to support later verification that wall thicknesses and reinforcement details of the strengthened exterior and interior walls in the ABWR AIA structural analyses are appropriately transferred to the civil-structural drawings to ensure that the AIA conclusions are maintained.

In addition, the team noted that heating, ventilation, and air conditioning (HVAC) duct and cable routing has not been established in the DCD; however, MFN-16-027 credits HVAC duct locations as key design features. The assessment contains a list of rooms that does not contain any credited core cooling equipment. Installing HVAC system(s) (including ducting, equipment, and cables) used to support credited core cooling equipment in one of these rooms could invalidate the conclusion of damage-free credited equipment. The NRC inspection team noted this observation to support later verification that HVAC placement and routing does not invalidate AIA conclusions that the reactor core remains cooled.

b.2 Quality Requirements

The NRC inspection team reviewed the work instructions GEH uses to evaluate design changes that could affect the ABWR design. Specifically, the team reviewed Procedure WI-03-113-04, “NPE Product Design Change Control Evaluation of Changes Affecting NRC Design Certification Documents,” Revision 2.0, dated September 5, 2014.

Step 2.3, “Impacts of Aircraft Impact Assessment,” states the effect of the changed design feature or function capability on the original assessment must be considered in the proposed changes to the design as it exists in the certified DCD, or application, to ensure that the modified design features and functional capabilities continue to meet the aircraft impact assessment requirements.

The NRC inspection team verified that the inputs, assumptions, methodology, assessment results, and conclusions were applied consistent with GEH’s quality assurance documents.

b.3 Software

The NRC inspection team reviewed the following computer codes used in the structural analysis for the AIA: TeraGrande, a software used for final analyses implementing the ANACAP-U concrete material constitutive modeling software. The NRC inspection team verified that GEH had verified, validated and benchmarked the codes for the applications assessed, consistent with Appendix C of NEI 07-13, and GEH had adequately documented the validation and verification.

c. Conclusions

The NRC inspection team concluded that with the exception of Violation 05200045/2016-201-01, documented in Sections 2.b.1, 3.b.1, and 3.b.2 of this inspection report, the documentation and quality assessment performed by GEH for the AIA is acceptable.

5. Entrance and Exit Meetings

On September 12, 2016, the NRC inspection team discussed the scope of the inspection with representatives from GEH. On September 16, 2016, the NRC inspection team presented the inspection results and observations during an exit meeting with representatives from GEH.

ATTACHMENT

1. PERSONS CONTACTED

Name	Affiliation	Entrance	Exit	Interviewed
Stacy Smith	NRC	X	X	
Ryan Nolan	NRC	X	X	
Dennis Andrukat	NRC	X	X	
George Wang	NRC	X	X	
Ata Istar	NRC	X	X	
Mark Caruso	NRC	X	X	
Dr. Alex Brown	SNL	X	X	
Dr. Christopher Jones	SNL	X	X	
Terry Jackson	NRC		X	
Randy James	ANATECH/SI	X	X	X
Gary Hayner	Jensen Hughes	X	X	X
Dan Parker	ANATECH/SI	X	X	
Patricia L. Campbell	GEH	X	X	X
J. Alan Beard	GEH	X	X	X
Matthew Heiser	GEH	X	X	
Michael Arcaro	GEH	X	X	
Tanya Kirby	GEH	X	X	X
Lenny Laskowski	GEH	X	X	X
Gary Miller	GEH	X	X	X
R. Taylor Blake	GEH	X	X	
David Hinds	GEH	X	X	X
Lee Dougherty	GEH	X	X	
Louis Quintana	GEH	X		
Antonio Dias*	NRC		X	

* Attended by phone

2. Inspection Procedures Used

Inspection Procedure 37804, “Aircraft Impact Assessment,” dated February 9, 2012.

3. List of Items Opened, Closed, and Discussed

Item Number	Status	Type	Description
05200045/2016-201	Open	NOV	10 CFR 50.150(a)(1)

4. Documents Reviewed

Documentation and Quality Assessment and Systems-Loss Assessment

- Condition Report 20340, dated August 30, 2016
- Letter from GEH to the NRC, "GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application – ABWR DCD Changes for Aircraft Impact Assessment (AIA) – Key Design Features," dated September 2, 2016
- WI-03-113-04, "NPE Product Design Change Control Evaluation of Changes Affecting NRC Design Certification Documents," Revision 2.0, dated September 5, 2014
- Jensen Hughes Report #C0102080007-9536, "Aircraft Impact Assessment for Fuel Cooling, Report on the GEH-ABWR DCD, Revision 6 Design," Revision 4, dated September 1, 2016
- "ABWR Design Control Document," Document # 25A5675, Revision 6, dated February 2016
- MFN-16-027, "GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application – ABWR DCD Changes for Aircraft Impact Assessment (AIA) - Key Design Features," dated September 2, 2016
- GE Nuclear Energy, "ABWR Standard Safety Analysis Report," Document # 23A6100, Revision 1, issued 1993.

Fire Damage Assessment

- Jensen Hughes Report #C0102080007-9536, "Aircraft Impact Assessment for Fuel Cooling, Report on the GEH-ABWR DCD, Revision 6 Design," Revision 4
- Structural Integrity (Anatech) Report #1600262.401, Revision 1 (see Figure 5-1, Figure 5-2 and Chapter 5, Conclusions)
- GEH-ABWR DCD, Revision 6
- MFN-16-027, "GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application – ABWR DCD Changes for Aircraft Impact Assessment (AIA) - Key Design Features," dated September 2, 2016
- ABWR DCD CB & RB Fire Area Color Code (tool aid showing safety divisions)

Structural Damage Assessment

- ANATECH Corporation, "Evaluation of Aircraft Impact on GEH-ABWR Plant Design - Structural Response Analysis," Report 1600262.401.R0, dated August 25, 2016
- ANATECH Corporation, "Evaluation of Aircraft Impact on GEH-ABWR Plant Design - Structural Response Analysis," Report 1600262.401, Revision 0 to Revision 1 Change List and markups, dated September 13, 2016.
- General Electric Hitachi Nuclear Energy Company, "ABWR Design Control Document," Document # 25A5675, Tier 2, Revision 6, dated February 2016.

- MFN-16-027, "GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application - ABWR DCD Changes for Aircraft Impact Assessment (AIA) - Key Design Features," dated September 2, 2016.
- ANATECH Corporation, V&V Report, "Teragrande Qualification Package for Aircraft Impact," Version 13905, Revision 0, dated September 9, 2016
- ANATECH Corporation, "Modification of ANACAP concrete analysis software to include the effects of confinement," Company Proprietary Information, dated January 2016
- The Jensen Hughes, "Aircraft Impact Assessment for Fuel Cooling, Report on the GEH-ABWR DCD, Revision 6 Design," Report #C0102080007-9536, Revision 4, dated September 1, 2016
- FOAKE Drawing # 24156-1U71-S5557, Revision 1, "Reactor Building Partition Walls Reinforcing Schedule."
- FOAKE Drawing # 24156-1U71-S5001, Revision 1, Note 2 "Concrete shall have minimum compressive strength of 5000 psi.
- ANATECH Record of Analysis GEH-ABWR, PO/Contract #: 437102694 R3, Project #1600262.00, "Evaluation of Aircraft Impact on GEH ABWR Plant Design"
- Engineering Change Authorization (ECA) Number CP1-1-ECA-0001, Revision 0, dated December 20, 2010

5. ACRONYMS USED:

ABWR	advanced boiling water reactor
ADAMS	Agencywide Documents Access and Management System
AIA	aircraft impact assessment
ATWS	anticipated transient without scram
CFR	*Code of Federal Regulations*
DCD	design control document
DCIP	Division of Construction Inspection and Operational Programs
ECCS	emergency core cooling system
FSAR	final safety analysis report
GEH	GE Hitachi Nuclear Energy
HVAC	heating, ventilation, and air conditioning
IP	inspection procedure
LOCA	loss of coolant accident
NEI	Nuclear Energy Institute
NRC	(U.S.) Nuclear Regulatory Commission
NRO	Office of New Reactors
PRA	probabilistic risk analysis
PSID	pounds per square inch differential
QA	quality assurance
QVIB	Quality Assurance Vendor Inspection Branch
RCCV	Reinforced Concrete Containment Vessel
RCS	reactor coolant system
RHR	residual heat removal system
SFP	spent fuel pool
SSC	systems, structures, and components
U.S.	United States (of America)