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# SUPPLEMENTARY DOCUMENT



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| **Title:** | **SIMCON Simulation Case Study for Alion Nuclear Utility Risk Simulation** | | |
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| **To:** | Prospective and Existing Clients | **Date:** | 04/30/2020 |
| **From:** | SIMCON Solutions LLC | **Revision #:** | 2 |
| **Description:** | This case study describes a project where SIMCON supported Alion Science and Technology in developing, verifying, maintaining, and documenting a simulation model that predicts plant failure risk for nuclear utilities in accordance with GSI-191. | | |

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## 1. Purpose

This case study describes a project where SIMCON supported the engineering services company Alion Science and Technology (Alion) in the development, maintenance, quality assurance, documentation, and commercialization of a custom simulation program that predicts core damage risk for nuclear utilities. This work was performed between July 2013 and January 2019, and included several plant-specific projects. SIMCON remains partnered with Alion for ongoing work on this project.

This case study was prepared by SIMCON in conjunction with our client. It provides background on the government mandate that prompted the work as well as the custom simulation program developed to address that mandate. The case study also outlines the client challenges, the SIMCON solution approach, and the key takeaways from the project. It reflects both our experience working on the project and our client's perspective of working with SIMCON on this particular simulation project.

## 2. Project Background

Given the specialized nature of the work SIMCON performed for Alion, this case study begins by providing some background information on the government mandate that prompted this work, as well as the custom simulation program developed to address that mandate. Section 2.1 describes the government-mandated safety concern that prompted this work, Section 2.2 describes the prototype software first developed to support nuclear utilities in resolving this safety issue, and Section 2.3 describes how this prototype was licensed to Alion for commercial use.

### 2.1. Generic Safety Issue 191 (GSI-191)

In September 1996, the U.S. Nuclear Regulatory Commission (NRC) issued Generic Safety Issue 191 (GSI-191), a safety issue which all domestic nuclear power plants must adequately address through a formal license amendment submittal process. In order to better understand the purpose and meaning of GSI-191 within the context of this project, it is helpful to understand the accident scenario this safety issue addressed as well as the emergency systems installed at the nuclear plants designed to circumvent catastrophic failure as a result of these accidents.

Ordinarily, coolant (i.e., water) is constantly circulated through the core to maintain safe temperatures. The purpose of an emergency core cooling system (ECCS) is to counteract a loss-of-coolant accident (LOCA) by circulating coolant from an emergency reserve to prevent catastrophic overheating and meltdown. A LOCA is an accident where one of the pipes responsible for circulating coolant through the core breaks, thereby interrupting or significantly impeding the flow of coolant to the core, potentially leading to a meltdown.

Moreover, coolant is circulated through these pipes at an extremely high pressure. When a pipe breaks, the immense pressure of the water jet emanating from the break blows a variety of debris (e.g., piping insulation and coatings) off of the pipe and surrounding surfaces, which falls into a water reservoir at the bottom of the core containment building called a sump. This sump contains the backup coolant that is used by the ECCS to cool the core in the event of a LOCA. One or more large strainers are used to filter any debris that has accumulated in the sump as a result of the LOCA out of the coolant routed to the core.

GSI-191 addresses the concern that this debris could clog the ECCS suction strainers (or sump screens) during a LOCA and prevent the ECCS from performing its safety function. Specifically, the GSI-191 mandate required nuclear plants to:

- Determine whether debris could clog ECCS suction strainers or sump screens during a LOCA
- Address the risk of debris blocking flow paths and damaging equipment downstream of the ECCS strainers
- Ensure adequate net positive suction head (NPSH) across ECCS pump(s) during a LOCA

### 2.2. CASA Grande Prototype

To help nuclear utilities resolve GSI-191, engineers at Los Alamos National Labs (LANL) partnered with academic research teams to develop a simulation program that automates the process of analyzing plant ECCS failure risk for postulated LOCA events. A prototype of this software was exercised for the first

time in December of 2011, and is now referred to as the Containment Accident Stochastic Analysis (CASA) for GSI-191 Resolution AND Evaluation (Grande) analysis suite. The CASA Grande software suite is constructed of statistical and physical models that are used in combination to calculate ECCS failure probabilities during long term cooling following a loss of coolant accident.

Inputs to the CASA Grande simulation program include:

- Plant-specific containment CAD models
- User-defined specifications (e.g., debris type definitions, ECCS equipment configurations)
- User-defined probability distributions (e.g., LOCA break size distributions)
- Physical parameters (e.g., void fractions, debris transport fractions)

CASA Grande supports the resolution of GSI-191 by:

- Randomly sampling the physical plant parameter values related to LOCA sequences
- Simulating the progression of plant-specific LOCA events over time
- Estimating risk for each of several modes of plant failure that may result from a LOCA
- Accounting for ECCS operator actions and mitigation event timing
- Evaluating thousands of postulated LOCA-initiating events (i.e., pipe breaks) and aggregating results in order for form an overall risk estimate

Standard outputs from each CASA Grande analysis include:

- Conditional failure probabilities specific to several modes of ECCS failure
- The increase in core damage frequency (commonly referred to as ΔCDF)
- Risk-dominant pipe break locations (i.e., welds)
- Distributions of debris combinations
- Accident progression timing

This prototype simulation program was based on the system configuration of the South Texas Project (STP) nuclear utility. As a result, many of the programming constructs developed in this initial prototype could not be used to support GSI-191 resolution efforts for other utilities without further modification and generalization of the source code.

### 2.3. CASA Grande Commercialization

In 2013, LANL filed a copyright disclosure for CASA Grande and soon after established an exclusive commercial licensing agreement with Alion. Under the terms of the exclusive license, Alion could modify, market, and apply the CASA Grande code for revenue generation so long as periodic improvements to the code reverted back to LANL for noncommercial, government use. From a corporate perspective, CASA Grande constituted a business investment for Alion that would help the company grow its market base among commercial nuclear utilities.

## 3. Client Challenges

Alion sought to make numerous improvements to the CASA Grande source code to support their consulting services and actively develop a market for users in the nuclear utility community. However, the Nuclear Services Division (NSD) of Alion did not possess the internal expertise in statistics, computer science, or software quality assurance necessary to adequately achieve these project objectives in-house. Therefore, Alion contracted SIMCON to engage in a long-term partnership and address the following client challenges:

- Acquire additional expertise and bandwidth in statistics and software development
- Develop and verify new features and enhancements for CASA Grande
- Establish and manage a comprehensive software quality assurance program
- Defend CASA Grande methodologies and results against NRC scrutiny
- Position CASA Grande software for public release and licensing
- Design and conduct analyses to support utilities with license submittals and GSI-191 resolution
- Respond to ongoing inquiries from nuclear utility clients (e.g., individual nuclear utilities)

In summary, Alion needed help transitioning the prototype CASA Grande program into a commercial software package that could stand up to NRC scrutiny and be used to support nuclear power plants in the successful resolution of GSI-191. Their internal engineering team was not equipped to address these client challenges, and Alion contracted SIMCON to provide the technical support and expertise necessary to meet their objectives.

## 4. SIMCON Solution Strategy

SIMCON began working extensively with the Alion NSD engineering team to define their challenges and objectives, as well as the simulation design specifications and software quality assurance requirements. Once all of this prerequisite data was collected, SIMCON began reviewing and updating the CASA Grande source code to better position the simulation program to achieve the client objectives. The first phase of CASA Grande software development and verification effort involved:

- Refactoring the source code to streamline model development, debugging, and verification
- Generalizing the source code to support nuclear utilities with different system configurations (e.g., support alternative ECCS pump and strainer configurations)
- Introducing Latin Hypercube Sampling (LHS) to randomly sample and propagate input parameter values in support of the evaluation of numerous postulated LOCA events
- Developing and verifying new features in response to evolving NRC and plant requirements (e.g., addition of chemical effects, coatings analyses, WCAP-16530 support, etc.)
- Expanding user interface (UI) capabilities to support interactive analyses (e.g., debris generation and transport analyses for postulated LOCA events)

SIMCON then began working with the Alion NSD team to design and manage a comprehensive software quality assurance effort for CASA Grande. This effort aimed at supporting Alion in its defense of CASA Grande methodologies and results against NRC scrutiny, and consisted primarily of:

- Designing and implementing a comprehensive software quality assurance program
  - Verifying and validating all aspects of the CASA Grande source code
  - Documenting all theory (i.e., equations, methodologies) implemented in CASA Grande
  - Performing and documenting all necessary quality assurance tests (e.g., unit tests)
- Defending CASA Grande methodologies and results against NRC scrutiny
  - Responding to NRC requests for additional information
  - Supporting Alion NSD in response to formal NRC audits of software and methodologies
  - Defending CASA Grande analysis methodologies to NRC staff remote and in-person

SIMCON also helped Alion position the custom CASA Grande simulation program for public release and end-user licensing. This effort was composed of the following major work tasks:

- Generating software release documentation (e.g., ReadMe, Release Notes, User Guide)
- Developing executable versions of CASA Grande program and an associated installer
- Designing end user licensing features to control access and redistribution of CASA Grande

Lastly, SIMCON provided ongoing technical support for the design, management, and execution of consulting services for a number of Alion clients (i.e., nuclear utilities). SIMCON served in both management and technical roles for these consulting projects, which included:

- Leveraging CASA Grande to support utilities with license submittals and GSI-191 resolution
- Managing Alion NSD engineering teams in support of client-specific plant failure analyses
- Developing and verifying new features and enhancements to satisfy client-specific objectives
- Responding to ongoing inquiries from nuclear utility clients (e.g., individual nuclear utilities)

## 5. Results and Key Takeaways

SIMCON's ongoing partnership with Alion Science and Technology has provided innumerable benefits to their Nuclear Services Division. To date, our working relationship with Alion has spanned several years and numerous consulting projects. During that time, SIMCON helped Alion:

- Successfully defend CASA Grande against NRC scrutiny
- Support the successful resolution of GSI-191 for STP and Callaway Utilities
- Expand their consulting services to support the license submittals and GSI-191 resolution efforts of several other plants (e.g., Palisades, Vogtle, Fermi, Diablo Canyon, PWR Owners Group, BWR Owners Group)
- Establish a professional and comprehensive software quality assurance program
- Bring the custom CASA Grande simulation program to market
    - Several nuclear utilities have purchased and current own a software license for CASA Grande

Figure 1 provides a visual depiction (shown in CAD software) of a postulated LOCA event simulated in CASA Grande for a given nuclear utility. The red area in this figure represents the "zone of influence" (ZOI) for the water jet emanating from the pipe break, where all containment surfaces (e.g., pipes, walls) within this zone generate debris (e.g., insulation, coatings) that accumulates down in the containment sump.

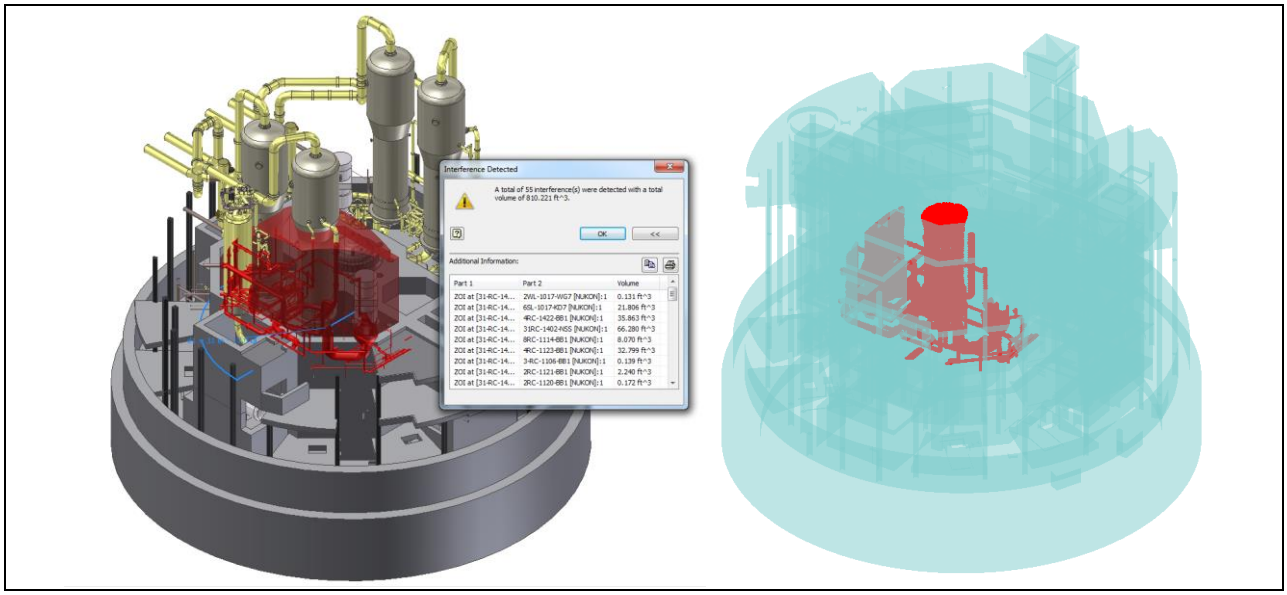


Figure 1: Visual Depiction of LOCA Event Simulated in CASA Grande

These figures are reproduced in this case study to demonstrate the value of the CASA Grande simulation program for visualizing loss-of-coolant accidents. In this way, SIMCON was able to provide Alion with extensive, ongoing support in their internal software development and quality assurance efforts, as well as their external consulting services.