Atomic Alchemy Inc. Position Paper:

Non-Power Modular Reactors: Multi-Unit Site Phased Construction Plan

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Non-Proprietary

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EXECUTIVE SUMMARY

All nuclear reactors (power and non-power) are licensed to operate as utilization facilities under Title 10 in accordance with the Atomic Energy Act (AEA or Act) of 1954. The regulation of non-power reactors (historically) under 10 CFR 50, have mostly been classified as Research and Test Reactors (RTR) under 10 CFR Part 50.21(c) or 10 CFR 50.22. The Atomic Alchemy Non-Power Production Utilization Facility (NPUF) construction license and operating license applications will be submitted under Title 10, Part 50.22.

The NRC Staff issued a Safety Analysis Report (SAR) format and content guide (NUREG-1537, Part 1) in 1996 for NPUF license applicants. A companion document was also issued in 1996, NUREG-1537 Part 2 for the Staff to use to review and evaluate the SAR of NPUF facilities. NUREG-1537, Part 2 states*: "…thus, even though many of the regulations of Title 10 apply to both power and non-power reactors, the regulations will be implemented in a different way for each category of reactor consistent with protecting the health and safety of the public, workers, and the environment. Because the potential hazards may also vary widely among non-power reactors, regulations also may be implemented in a different way within the non-power reactor category."*

For modular design nuclear power plants, Title 10, Part 52.47(c)(3) requires an evaluation of the module operating configurations, considering the shared systems and interactions, and interface requirements, as well as identifying any potential restrictions necessary during module construction and startup. For non-power reactors there are no such requirements under NUREG-1537[1]. However, similar requirements are included under Title 10, Part 50.34(a)(11) and Part 50.34(b)(6)(xii). While the Atomic Alchemy Versatile Isotope Production Reactors (VIPR) are similar to RTRs in terms of their power level and potential consequences, there are notable differences. The VIPRs are expected to operate at full power for prolonged periods.

The NRC's principle of good regulation for efficiency states: "*where several effective alternatives are available, the option which minimizes the use of resources should be adopted.*" By applying this principle to the Atomic Alchemy project, Atomic Alchemy will focus its design on ensuring it meets the underlying intent of the applicable Title 10 regulations, which is to provide reasonable assurance of adequate protection of the public health and safety. Atomic Alchemy Inc. has determined that these Title 10, Part 50 requirements could be applicable to its NPUF design. Atomic Alchemy also acknowledges the interest the NRC and general public would have with respect to placing potential restrictions on the operating configurations during modular construction (the Part 52 regulation) and how this can be safely accomplished for the construction of its NPUF.

Therefore, the purpose of this position paper is to address both Part 50 and Part 52 regulatory requirements and demonstrate for the staff a comprehensive outline plan of the construction strategies, innovative design approaches, and administrative controls to be used by Atomic Alchemy Inc. that will facilitate the efficient, cost-effective, and safe construction and licensing of their Non-Power Utilization Facility. This position paper will become part of the SAR in Chapter 1, Appendix F, "Non-Power Modular Reactors Constructed on a Multi-Unit Site".

[1] NUREG-1537, Part 1, and ISG NUREG-1537, Part 1

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ABBREVIATIONS

A/E	architect and engineer
AOO	anticipated operational occurrence
ASME	American Society of Mechanical Engineers
BDC	Baseline Design Criteria (or Criterion, as applicable)
BPVC	boiler pressure vessel code
BTP	branch technical position
BWR	boiling water reactor
CFR	Code of Federal Regulations
DBE	design basis event
DCS	distributed control systems
DEB	double ended break
DSA	deterministic safety analysis
ECCS	emergency core cooling system
EDMS	Enterprise Data Management System
EPC	engineering, procurement, and construction
ESF	engineered safety feature
EVM	earned value management
FHA	fire hazards analysis
FRD	facility requirements document
FSAR	Final Safety Analysis Report
FNTA	functional task analyses
FTA	fault tree analysis
GDC	General Design Criteria (or Criterion, as applicable)
HEP	human error probability
HFE	human factors engineering
HRA	human reliability analyses
HSI	human system interface
IAEA	International Atomic Energy Agency
IAW	In accordance with
ISI/IST	inservice inspection/inservice testing
KSA	knowledge, skills, and abilities

LCO	limiting condition for operation
LOLA	loss of large area
LOOP	loss of offsite power
LWR	light-water reactor
MCR	main control room
NFPA	National Fire Protection Association
NRC	Nuclear Regulatory Commission
NPR	non-power reactor
NOUE	notification of unusual event
NPUF	Non-power Production and Utilization Facility
ORAT	Operational Readiness Assessment Team
PDC	Principal Design Criteria (or Criterion, as applicable)
PDMS	Plant Design Management System
PIE	postulated initiating event
PSAR	Preliminary Safety Analysis Report
PWR	pressurized water reactor
QAPD	Quality Assurance Program Document
RG	regulatory guide
SAFDL	specified acceptable fuel design limit
SAR	Safety Analysis Report
SER	Safety Evaluation Report
SREC	standard radiological effluent controls
SSC	structures, systems, and components
TMI	Three Mile Island
TR	topical report
UFSAR	Updated Final Safety Analysis Report
UPS	uninterruptible power supply
VHL	very heavy lift
VIPR	Versatile Isotope Production Reactor
WCAP	Westinghouse Commercial Atomic Power
WG	water gauge

1.0 INTRODUCTION

The design of the Atomic Alchemy NPUF includes a complement of four (4) Versatile Isotope Production Reactor (VIPRs) and two (2) radioisotope processing module buildings (see Figure 17.01). The construction of the facility Structures, Systems, and Components (SSC) and the sequential construction, testing, and startup of subsequent VIPRs (and radioisotope processing modules) will be designed to minimize the impact on the operating Non-Power Reactors (NPRs) and radioisotope process production SSCs.

This position paper will describe how the design and proposed construction plan of the Atomic Alchemy facility complies with the elements of its principal design criterion that are based on 10 CFR 50 Appendix B, General Design Criterion 2, 3, 4, 5, 22, and 24 and other applicable Title 10 regulations.

The Atomic Alchemy reactors are designed such that each VIPR reactor can be safely constructed and operated independent of the other VIPRs. The Non-power Production and Utilization Facility (NPUF) will include design features that ensure the independence and protection of safety-related systems during Design Basis Events (DBE) that occur during construction, testing, and startup of other VIPR and radioisotope modules. The redundant safety-related systems of both the VIPR and radioisotope processes will be designed to meet single failure criteria.

Shared systems will be designed for operational reliability and availability to minimize ongoing construction related restrictions on the VIPR operating configurations during normal modes of operation. The shared systems will include design features such as redundancy, spare capacity, isolation, and consideration of system interfaces. These advanced design features will minimize the necessity of placing an operating VIPR or Radioisotope Process Production train completely out-of-service for construction, startup, or testing configurations of the under construction VIPR (or Radioisotope Process Production SSCs).

2.0 MULTI-UNIT KEY REGULATORY POLICY CONSIDERATIONS

The operational characteristics and design basis of the Atomic Alchemy NPRs are fundamentally different from those of large, commercial nuclear power reactors for which the Title 10 regulations were originally created. The key difference in design of the Atomic Alchemy NPRs is their very small inventory[2] of fission products in the reactor core, as compared to currently licensed power reactors. The Atomic Alchemy accident analyses will validate that even for catastrophic scenarios (Beyond Design Basis Events[3] (BDBE)) in which there are multiple failures of radioisotope fission or reactor fuel product barriers the BDBE still would not lead to a significant adverse impact on the health or safety of the public.

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[2] In addition to a smaller quantity of nuclear fuel in the core, Atomic Alchemy will be utilizing the reactors to irradiate other quantities of radioactive materials that are stored and then processed in adjacent module buildings.

[3] While the NRC position on 10 CFR 50.155 in the public register (Federal Register / Vol. 84, No. 154 / Friday, August 9, 2019) stated that BDBE would not be applicable to a non-power reactor facility, that staff determination was made at a time when non-power test reactor facilities were limited to a single reactor. Therefore, the applicability of a BDBE transient on a multi-unit reactor and radioisotope processing NPUF facility will be conservatively evaluated.

For the purposes of this paper, this section will provide an alignment of the relevant existing Title 10 regulatory framework to the inherent passive simplified design of the Atomic Alchemy NUPF facility with respect to its construction plan. Atomic Alchemy performed a Regulatory GAP Analysis[4] to be provided in FSAR Chapter 1, Appendix G. Atomic Alchemy submitted a preliminary GAP analysis of the related light-water reactor (LWR)-based Title 10 regulations identified in NUREG-0800, submitted in Atomic Alchemy Inc. Letter AAL-2021-007 "Supplement 1 to the Submittal of the Standard Review Plan Conformance for Atomic Alchemy's Non-Power Production and Utilization Facility", Agencywide Documents Access, and Management System (ADAMS) Accession No. ML21196A515, dated June 25, 2021.

2.1 10 CFR 50 Appendix A

Atomic Alchemy provided its principal design criteria to the NRC as a topical report in Atomic Alchemy Inc. Letter AAL-2020-004, "Principal Design Criteria for Atomic Alchemy's Non-Power Production and Utilization Facility" Agencywide Documents Access and Management System (ADAMS) Accession No. ML21169A044, dated June 18, 2021. Atomic Alchemy used 10 CFR Part 50 Appendix A General Design Criteria (GDC) and 10 CFR 70.64(a) Baseline Design Criteria (BDC) as a minimum basis for developing its principal general design criteria to meet the regulatory requirements of 10 CFR 50.34(a)(3) for both its NPR reactors and its radioisotope process production facilities. Provided herein is a brief summary of the conclusions of the Atomic Alchemy regulatory gap analysis of relevant general design criterion as applied to a multi-unit site.

GDC Criterion 2 – Design Basis for Protection Against Natural Phenomena

The safety-related structures, systems, and components that are vital to mitigating the effects of accidents and provide the shutdown capability of the reactor and to the radioisotope production processes are designed to withstand the maximum probable natural phenomena at the Atomic Alchemy NPUF site without loss of the capability to perform their safety-related functions. Seismic and quality group classifications are conservatively applied to systems, structures, and components (SSC) related to safety. Atomic Alchemy's FSAR Chapter 15 will identify the co-incident conservative site conditions for each postulated accident transient. Appropriate combinations of structural loadings from transients, normal operation and environmental phenomena are accounted for in the facility design. FSAR Chapter 1, Appendix B, Section 2 will describe Atomic Alchemy's compliance with Site Characteristics.

This also satisfies the intent of 10 CFR 70.64(a)(2).

GDC Criterion 3 – Fire Protection

The safety-related structures, systems, and components are designed to minimize the probability and effect of fires and explosions. Noncombustible and fire-resistant materials are used on components of safety-related systems, and elsewhere in the facility where fire is a potential risk to safety-related systems. Firefighting systems are designed such that their

[4] The Atomic Alchemy Regulatory Gap Analysis results will be subdivided into Appendices in FSAR Chapter 1 and Chapter 3, with an overall summary in Chapter 1 Appendix G, there will be separate appendices for NUREG-0800, NUREG-0737, NUREG-0933, and 10 CFR 50 Appendix A.

rupture or inadvertent operation will not prevent any safety-related systems from performing their design functions. Atomic Alchemy will perform a Fire Hazards Analysis of each area within the facility. FSAR Chapter 9, Appendix A will describe Atomic Alchemy's fire protection program and fire hazards analysis. The Fire Hazard Analysis that will be provided in FSAR Chapter 9, Appendix A will also evaluate the Loss of Large Area (LOLA) of the facility due to fires or explosions.

This also satisfies the intent of 10 CFR 70.64(a)(3).

GDC Criterion 4 – Environmental and Missile Design Bases

Safety-related structures, systems, and components are designed to accommodate the effects of both interior and exterior generated missiles. Protection from external missiles, including those generated by natural phenomena, is provided by the external walls and roof of the Seismic Category I module building structures. Details of the design features and construction of these structures, systems, and components to protect against these effects will be described in FSAR Chapter 3, Section 6, and Section 8. The analysis of the postulated events will be discussed in FSAR Chapter 15, Section 6 Reactor Accidents and Section 8, Radioisotope Production Process Accidents. The dynamic effects of postulated pipe ruptures and pipe whip are minimized based on the application of the leak-before-break approach to safety related ASME Class 1 and 2 piping. Because the reactors are located within light-water pools open to the atmosphere, the probability of fluid systems piping over pressurization and rupture are not credible transient scenarios. Because the VIPR is non-power, missiles generated by turbine blades is not a credible transient scenario. Atomic Alchemy high energy and moderate energy piping located outside of the confinement module building will also be analyzed for breaks. A pipe break hazards evaluation will be part of the Atomic Alchemy piping design. The evaluation will be performed for high and moderate energy piping to confirm the protection of systems, structures, and components which are required to be functional during and following a design basis event. The Atomic Alchemy VIPR will be designed to be passively safe; it will have the capability to be shut down and maintain a safe shutdown condition and the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures of 10 CFR 50.34 without the use of any active systems or operator actions.

This also satisfies the intent of 10 CFR 70.64(a)(4).

GDC Criterion 5 – Sharing of Structures, Systems and Components

The VIPR light-water pool (which also contains each reactor's spent fuel) share a common light-water radioisotope transfer canal (TTW) with one other VIPR light-water pool. The TTW system can also function as an "emergency core cooling" type of system, identified in the design as the Reactor Decay Heat Removal System (DHR) which will be an additional source of makeup water for both of the reactor light-water pools that are connected to it. The sharing of this DHR makeup water does not impair the capability of either reactor safety related systems to perform their intended safety functions. The volume of makeup water stored in the light-water transfer canal pool is sufficient for the decay heat removal from each reactor pool for 72 hours.

After 72 hours the reactor light-water pools are capable of dissipating decay heat of both the reactor and the spent fuel located within the light-water pool for 30 days.

The Atomic Alchemy facility will share the 1E DC UPS systems between radioisotope, target fabrication, and radwaste processes (See Table 16.01 for a list of the radioisotope safety related shared systems, see Atomic Alchemy compliance with Regulatory Guide 1.32, position C, and Regulatory Guide 1.81 position C.3 in FSAR Chapter 1, Appendix A, and also see Section 7.1 of IEEE Std. 308-2001[5]).

Each reactor[4] has its own dedicated 1E DC UPS system. With this one exception (the Light-water Radioisotope Transfer Canal), only non-safety-related systems will be shared between the reactors. (see Table 16.02 for a preliminary list of shared non-safety-related systems) Although non-safety-related, the shared systems will be designed for operational reliability and availability to minimize restrictions on VIPR operating configurations during normal modes of operation. The non-safety-related shared systems will include design features such as redundancy, spare capacity, isolation, and consideration of system interfaces. These design features minimize the effects of reactor out-of-service and testing configurations in order to allow continued full-power operation of the reactors and other non-reactor processes. FSAR Chapter 1, Appendix B, will describe Atomic Alchemy's conformance with SRP 8.3.1, 8.3.2, and 9.2.5 and FSAR Chapter 1, Appendix A, will describe Atomic Alchemy compliance with regulatory guides 1.26, 1.27 and 1.81.

The Atomic Alchemy safety-related DC power system design also meets the intent of GDC 18. The surveillance testing of the Class 1E DC UPS systems will be performed as required by the Technical Specifications. Atomic Alchemy Technical Specification Surveillance Requirements (SR) 3.8.1, 3.8.2 and 3.8.5 will be provided for this purpose.

<u>GDC Criterion 22 – Protection System Independence</u>

The Reactor Protection System (IRP) will be designed with sufficient functional diversity and redundancy for a variety of postulated accidents. Redundancy provides confidence that reactor trips are generated on demand, even when the protection system is degraded by a single failure. Reactor trips are four-way redundant. The single failure criterion is met even if one channel is bypassed. Diverse and redundant protection functions automatically serve to mitigate the consequences of postulated transients. FSAR Chapter 15 will describe the extent to which the IRP functions for each event. In FSAR Chapter 7, Section 5, the IRP system will be described, including independence, diversity, single failure criteria, and separation between monitoring and controls.

[5] The NRC does not endorse this IEEE standard for the sharing of DC power in multi-unit sites in Regulatory Guide 1.32 and 1.81, however, it is Atomic Alchemy's position in this paper (and as previously stated in its Topical Report AA0-VIPR-21-PDC-00(P) submission dated June 18, 2021) that this non-endorsement is only applicable to sharing of DC power for the safe shutdown of reactors and not to other radioisotope processes.

The Atomic Alchemy instrumentation architecture will conform to NUREG/CR-6303 and will meet IEEE-603-1991, and the latest revision [6]of IEEE-379, IEEE-497, and IEEE-338 standards.

Sufficient redundancy and independence will be designed into the reactor protection systems so that no single failure or removal from service of any component or channel of a system results in loss of that protection function. Functional diversity and location diversity will be designed into the Atomic Alchemy system. High-quality components, conservative design and quality control, inspection, calibration, and tests will be used to guard against common-mode failure.

Control functions, reactor trip functions, engineered safety features functions, and monitoring & indication functions are divided into three levels containing: non-safety systems, safety systems, and non-safety diverse systems. During testing or maintenance, protection system functions will be provided to bypass a channel monitoring a variable for reactor trip. Although no setpoints need to be changed for bypassing, the coincidence logic will be automatically adjusted.

Future reactor and radioisotope process module I&C with connections to existing operating components will be isolated or partitioned at locations outside of the operating modules. Potential challenges caused by construction activities of the remaining reactors or radioisotope process components to the independence of the reactor protection system is addressed by work control processes and procedures that will ensure proper considerations for system interfaces and continued safe operations of the existing reactor units and/or radioisotope processes. These work control processes and administrative controls will be further described in this position paper.

<u>GDC Criterion 24 – Separation of Protection and Control Systems</u>

The Atomic Alchemy Protection and Safety Monitoring System (IMS) will be separate and distinct from the control systems. Control systems are dependent on the protection system for control signals that are derived from protection system measurements, where applicable. These signals are transferred to the control system by isolation devices classified as protection components. The Atomic Alchemy IMS system and components will be designed, tested, and qualified for operation in the Design Basis Event (DBE) environment in which the components are required to function. The protection systems are separate and distinct from the control systems. The adequacy of system separation will be verified during pre-operational testing. The failure of a single control system component or channel, or the failure or removal from service of a single component or channel common to the control and monitoring systems does not adversely impact the IMS system from continuing to be able to perform its intended design basis safety related functions. The removal of a protection division from service is allowed during testing of that division.

[6] Some of the latest versions of IEEE standards are not yet endorsed by a regulatory guide, but their use should not result in deviations from the design philosophy otherwise stated in any of the regulatory guides. Some also may have been endorsed by the NRC in SERs for other ALWR COL applications who similarly used later versions of industry codes and standards.

Future radioisotope process module I&C with connections to existing operating components will be isolated or partitioned at locations outside of the operating modules. Potential challenges caused by construction activities of the remaining radioisotope process components to the independence of the IMS will be addressed by work control processes and procedures that will ensure proper considerations for system interfaces and continued safe operations of the existing reactor units. These work control processes and administrative controls will be further described in this position paper.

2.2 10 CFR 50.12 - Specific Exemptions

Atomic Alchemy will submit specific Title 10 regulation exemption requests. For example, control room operators under 10 CFR 50.54(m), and some security elements under 10 CFR 73.55(r) and/or exemptions under 10 CFR 73.5 in accordance with the requirements of 10CFR50.12.

2.3 10 CFR 50.34(a)(11) - Identification of Potential Hazards to the Structures, Systems and Components Important to Safety of Operating Nuclear Facilities from Construction Activities on a Multi-Unit Site

While this regulation specifically mentions “power” reactors, Atomic Alchemy acknowledges that the potential hazards described by this regulation will exist among some of the new non-power reactor designs.

Atomic Alchemy is submitting this position paper early in the conceptual design as the preliminary framework for its proposed solutions to address applicable Title 10 regulatory concerns regarding multiple modular nuclear reactors constructed in phases on the same site for a NPUF facility. This framework will demonstrate the enhancements in safety achievability with advanced construction design planning and will reflect recent state of the art knowledge improvements regarding safety and construction design engineering innovations that will provide increased levels of safety. The Atomic Alchemy construction project methodology will build on the construction industry best practices as well as taking advantage of the lessons learned from previous ALWR design and construction activities.

This will allow the NRC and the general public to review and comment on the strategies and the design approach of Atomic Alchemy Inc. that will facilitate the efficient, cost-effective, and safe construction and licensing of their Non-power Utilization Facility.

2.4 10 CFR 50.34(b)(6)(vii) - Description of the Managerial and Administrative Controls to be Used to Provide Assurance that the Limiting Conditions for Operation Are Not Exceeded As a Result of Construction Activities at Multi-Unit Sites

While this regulation specifically mentions “power” reactors, Atomic Alchemy acknowledges that the potential hazards described by this regulation will exist among some of the new non-power reactor designs.

Atomic Alchemy is submitting this position paper early in the conceptual design as the preliminary framework for its proposed solutions to address applicable Title 10 regulatory concerns regarding multiple modular nuclear reactors constructed in phases on the same site for a NPUF facility. This framework will demonstrate the enhancements in safety achievability with advanced construction design planning and will reflect recent state of the art knowledge improvements regarding safety and construction design engineering innovations that will provide increased levels of safety. The Atomic Alchemy construction project methodology will build on the construction industry best practices as well as taking advantage of the lessons learned from previous ALWR design and construction activities.

This will allow the NRC and the general public to review and comment on the strategies and the design approach of Atomic Alchemy Inc. that will facilitate the efficient, cost-effective, and safe construction and licensing of their Non-power Production Utilization Facility.

2.5 10 CFR 50.54(m) - Minimum Requirements Per Shift for On-Site Staffing of Nuclear Power Units by Operators and Senior Operators Licensed Under 10 CFR Part 55

While this regulation specifically mentions "power" reactors, control room operators at NPRs are licensed under Title 10, Part 55. The potential hazards identified by this regulation can occur among the new non-power reactor designs.

The Atomic Alchemy NPUF design includes the monitoring and controlling of up to four NPRs from a single main reactor control room. Staffing can be reduced, and human errors minimized by utilizing human factors engineering (HFE) good practices and increased digital software automation. Operating up to 4 reactors from a single control room is a configuration that is not presently regulated in 10 CFR 50.54(m).

Additionally, Atomic Alchemy will provide a separate control room for monitoring and controlling non-reactor radioisotope evolutions and hot cell processes. There are no regulatory requirements for the staffing of this type of control room. Maintaining a separate control room for radioisotope processes allows the MCR operators to focus on just the control and operations of the reactors.

Atomic Alchemy will take an alternative approach to staffing the reactor control room and will request an exemption for the reactor control room staffing requirements identified in 10 CFR 50.54(m). This approach will be similar to the design approach taken by NuScale in their Standard Plant Design Certification Application. The approach involves use of applicable NRC guidance contained in NUREG-0711, Revision 3 "Human Factors Engineering Program Review Model", NUREG-1791, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)" and NUREG/CR-6838, "Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)".

The functional design requirements for the Atomic Alchemy reactor control room will follow an established robust set of guidelines for identifying operational conditions, tasks analyses, and functional allocations that will then be used as a basis for identifying the needed knowledge, skills, and abilities (KSA) for each control room operator position. Some tasks can be partially re-allocated to intelligent software monitoring systems. An in depth systematic HFE analysis and a functional requirements analysis of the control room design processes and operations for assuring the safe operation of the facility will be conducted to determine the conservative staffing requirements that will be submitted to the NRC as part of the exemption request.

Additionally, Atomic Alchemy will also include as part of the above analyses, an evaluation for providing additional reactor and radioisotope control room staffing during periods of construction, startup, and testing evolutions. Simulator studies[7] may also be used as a data input source regarding control room staffing during construction related activities. By running construction evolution and startup testing and accident scenarios that are postulated with the proposed staffing complement and collecting human performance measures, the adequacy of a proposed staffing plan will be demonstrated.

2.6 10 CFR 50.57 – Issuance of Operating License[8]

Atomic Alchemy will submit its pre-service test program to the NRC prior to performing the tests and following the start of Phase 1 construction. The elements of Phase 1 construction will be explained in greater detail later in this paper. Each Phase 1 module will be capable of being operated indefinitely and independent of any future Phase 2 or Phase 3 construction.

Partitioning of shared systems between Phase 1 SSCs and future Phase 2 or Phase 3 SSCs will be accomplished by design features (described later in this position paper) and startup and testing administrative controls (described later in this position paper) and will not require lengthy restrictions to be placed on any of the operating Phase 1 (or Phase 2) modules.

In accordance with the Atomic Alchemy's QAPD, Part I, Section 11.3, "Operational Readiness Assessment Program", upon completion of all Phase 1 pre-operational testing, and prior to commencing Phase 1 startup testing, a report (to be called the "Phase 1 Functional Area and Baseline Inspection Readiness Report") will be prepared for the Phase 1 construction SSCs. The report could be submitted to the NRC no later than 270 days before the scheduled initial loading of fuel date. This report will form the basis for supporting the Atomic Alchemy conclusion that the criterion of 10 CFR 50.57(a)(1), 10 CFR 50.57(a)(2) and 10 CFR 50.57(a)(3)(ii) have been satisfied by Atomic Alchemy for the Phase 1 modules and that the elements for the Phase 1 inspections identified in IP 69020, IP 69021, and IP 69023 have been satisfied and/or that there are no outstanding issues for which Atomic Alchemy has not developed adequate corrective actions for.

2.7 10 CFR 52.1 – Modular Reactor Design

The Atomic Alchemy NPUF construction license and operating license applications are submitted under Title 10, Part 50. For the most part, 10 CFR Part 52 regulations are not applicable to the Atomic Alchemy NPUF construction and license submission. Atomic Alchemy recognizes that the NUREG-1537 (circa 1996) and Title 10 Part 50 definitions have not kept up with the specific advancements in reactor facility design and the enhancements defined in the newer ALWR regulations of Part 52.

The Atomic Alchemy NPR design approach is consistent with and meets the definition of this Title 10 regulation. The Atomic Alchemy NPRs are identical nuclear reactors (modules), and each module is

[7] Atomic Alchemy may choose to develop a "digit twin" for training and performing construction transient analyses.
[8] The Atomic Alchemy Title 10 Part 50 construction and operating licenses' approach for licensing all 4 VIPR reactor modules and 2 radioisotope process modules will be addressed in a separate future position paper.

capable of being operated independently of the state of completion or operating conditions of any other NPR module or radioisotope process module co-located on the same site.

Additionally, the Atomic Alchemy radioisotope process is also modularized with two identical radioisotope process unit buildings (along with their respective supporting modules for radioisotope target fabrication, processing, shipping and radwaste). The modules that comprise the radioisotope process are also capable of being operated independent of the state of completion or operating condition of any NPR.

Each radioisotope process module building will be designed to have the flexibility to interface with any of the VIPR reactor modules.

2.8 10 CFR 52.47(c)(3) - Modular Nuclear Power Reactor Design Must Describe and Analyze the Possible Operating Configurations of the Reactor Modules with Common Systems, Interface Requirements, and System Interactions

The Atomic Alchemy NPUF construction license and operating license applications are submitted under Title 10, Part 50. For the most part, 10 CFR Part 52 regulations are not applicable to the Atomic Alchemy NPUF construction and operating license submissions. Atomic Alchemy recognizes that NUREG-1537, and the Title 10 Part 50 regulations and definitions have not kept up with the specific advancements in reactor design configurations and the enhancements defined in the newer ALWR regulations of Part 52. These potential issues nevertheless can exist among some of the new non-power reactor designs.

Atomic Alchemy is submitting this position paper early in the conceptual design as the preliminary framework for its proposed solutions to address applicable Title 10 regulatory concerns regarding multiple modular nuclear reactors constructed in phases on the same site for a NPUF facility. This construction framework will demonstrate the enhancements in safety achievability with advanced construction design planning and will reflect recent state of the art knowledge improvements regarding safety and construction design engineering innovations that will provide increased levels of safety. The Atomic Alchemy construction project methodology will build on the construction industry best practices as well as taking advantage of the lessons learned from previous ALWR design and construction activities.

This will allow the NRC and the general public to review and comment on these strategies and the construction design approach to be taken by Atomic Alchemy Inc. that will facilitate the efficient, cost-effective, and safe construction and licensing of their Non-power Production Utilization Facility.

3.0 DESIGN CONSIDERATIONS FOR MODULAR AND PHASED CONSTRUCTION

A successful nuclear facility development and construction project depends greatly on implementing a well-defined project design and management approach. The management of a nuclear project throughout its life cycle, from preliminary and initial design phase development to its final decommissioning, has proved to be a more challenging task than construction of a typical large capital cost industrial project. Given the aspects of nuclear technology, nuclear federal regulations, and state and local regulations, a successful nuclear project design must include delivering a sustainable solution that can be safely, securely, and reliably managed throughout its life cycle, while simultaneously involving many different stakeholders' interests in the process.

3.1 Standardization of the Design

The development of the Atomic Alchemy Facility Requirements Document[9] (FRD) outlines the site characterizations, conceptual design functions and design parameters and specifies the development of system requirements that will be translated into the necessary drawings, diagrams, P&IDs, figures, calculations, analysis, specifications, and interface requirements for the Atomic Alchemy Non-Power Production and Utilization Facility in accordance with 10 CFR 50.2. The FRD will be reviewed during a series of management and technical engineering reviews for functional analyses and evaluated for overall system and component optimization and standardization. The design and licensing basis documents developed from the FRD will provide traceability between regulatory requirements and the physical system designs for the NPUF facility.

The design of the four Atomic Alchemy VIPRs are identical. Each VIPR reactor confinement module (RCM) building is complimented by a reactor auxiliary module (RAM) building. These two modules comprise a collection of safety and non-safety systems, subsystems, and components that together constitute a completely modularized and independent NPR. For the purposes of minimizing the design description in this position paper, the VIPR confinement and auxiliary modules contain the reactor core, light-water pool, spent fuel pool storage, new fuel storage, hot cells, fire protection, reactor coolant pumps, reactor coolant heat exchanger, secondary chiller unit and pumps, tertiary cooling pumps and cooling towers, switch gear and MCC room, class 1E and UPS power supply, miscellaneous HVAC, and air filtration units.

The design of the Atomic Alchemy radioisotope process production module (PPM) units are also nearly identical. Each PPM is complimented by a radioisotope target fabrication module (MTM), shipping and receiving module (SRM) and radwaste processing module (RWM). This comprises a collection of safety and non-safety systems, subsystems, and components that together constitute a completely modularized and independent Radioisotope Process Production unit. For the purposes of minimizing the design description in this position paper, the PPM, MTM and RWM contain the main Mo-99 processing hot cell trains, radioisotope light-water transfer canals, electric steam boilers, off gas equipment, vitrification radwaste trains, hazardous chemical storage and recovery rooms, low level enriched uranium storage, recycling and recovery[10], low level waste temporary storage, switch gear and MCC rooms, class 1E UPS, fire protection, miscellaneous HVAC, and air filtration units.

The four modular NPR and two process module buildings are all supported by a common administration and service module (ASM) building. The ASM is also comprised of a collection of safety and non-safety systems, subsystems and components that support both the reactor and radioisotope processes. For the purpose of minimizing the design description in this position paper the ASM

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[9] This document is similar to a power reactor's Utility Requirements Document (URD).

[10] Atomic Alchemy may decide to amend their operating license to add recycling and recovering uranium to be re-used for target fabrication, sufficient compartments will be partitioned off in the original design to accommodate future expansion for these processes.

contains a main control room[11] for VIPRs and a separate control room for radioisotope processes, security offices, safeguards compartment, engineering and regulatory agency offices, commissary, human resources, fire protection, hot fabrication shop, health physics, emergency planning, a joint information center, training rooms, simulator rooms, class 1E and UPS power supply, control room safety related HVAC, miscellaneous non safety HVAC, and air filtration units.

3.2 Constructability Review

Atomic Alchemy along with its engineering, procurement, and construction (EPC) consortium including architect/engineer (A/E) partners will evaluate and optimize the final design in consideration of effective performance of the phased construction related activities. The overall construction knowledge and experience in planning, designing, procurement, and field construction operations of its consortium partners will minimize risks associated with large capital cost construction projects. As part of this review, the necessary planning for major subcontractors and a procurement strategy will be also developed. Considerations for utilizing Off-Site Modular Construction (OSMC) methodologies are also evaluated along with all-weather construction methods.

The overall design will be also reviewed for assuring that occupational radiation exposures are “As Low As Reasonably Achievable” (ALARA). ALARA consideration reviews include the plant design and integrated layout, the construction phases, additional considerations for shielding, traffic control, security, access control, and health physics.

The Atomic Alchemy consortium may also engage with additional potential equity partners, financiers, or credit insurance organizations in preparation for the construction project to secure any additional required financing that might be needed.

3.3 Technical Support

Atomic Alchemy will make a corporate level commitment to obtain and utilize effective technical support in decision making from its A/E engineering consortium partners as well as from its internal Technical Support Organization (TSO) on its NPUF project. Facility safety and improved performance is obtained by a clear understanding of the technical support functions and their implementation throughout the facility’s life cycle. Whether during the preparatory phase, design phase, construction, and startup phases and throughout the operations phase, good engineering technical support practices used for defining roles, responsibilities and interface requirements between Atomic Alchemy, its consortium A/E partners, vendors, and suppliers will support achieving the goals of a safe, reliable construction project.

Technical support is also essential during emergency situations. Emergency decision making requires timely and correct advice from technically knowledgeable and experienced persons. Atomic Alchemy recognizes the importance of implementing technical support into its emergency plan personnel as well as being necessary following an event for stabilization and recovery from dynamic transient conditions.

[11] An exception to 10 CFR 50.54(m)(2)(i) will be submitted to the NRC at a later date.

3.4 Safety Analysis Report (SAR), Technical Specifications (T/S), Technical Requirements Manual (TRM), and Offsite Dose Calculation Manual (ODCM)[12]

The Atomic Alchemy Design and Licensing Basis (D&LB) documents will be standardized and integrate the contents of its NPR VIPR design and Radioisotope Process Production design into single set of D&LB regulatory documents for all four VIPRs and the two radioisotope process, target fabrication, and radwaste modules. There may be some slight variances between the VIPRs or radioisotope processes in operational programs and/or at the procedural level to accommodate specific evolutions like tests, process sequences, surveillances, and prioritization of activities in the respective main control rooms.

The formatting of the SAR follows Regulatory Guide 1.70 and NUREG-0800. Guidance for Technical Specifications' formatting for non-power light-water reactors is provided in NUREG-1537, which invokes the format found in ANSI/ANS-15.1. The ANS-15.1 Standard guidance was reviewed as part of the creation of the Atomic Alchemy T/S. Although Atomic Alchemy's non-power light-water reactors do not have a NSSS vendor with an accompanying NRC endorsed Standard Technical Specification (STS) format to follow, Atomic Alchemy has determined to create a hybrid T/S format based on the format of revision 4 of the Standard Technical Specification (STS) found in NUREG-1431.

Additional Technical Specifications for the radiochemical, and chemical processing that is conducted outside of the reactor in the Atomic Alchemy facility will also be derived from the Accident Analysis in FSAR Chapter 15. The processes indicate that certain limits on process variables and engineered or administrative control measures are necessary to demonstrate safe operation of the radioisotope production facility. These will be included in the hybrid T/S.

As the final design progresses Atomic Alchemy may also adopt applicable Technical Specifications Task Force (TSTF) Travelers.

Based on the NRC's Final Policy Statement[13] on Technical Specification Improvements for nuclear power plants, and 10 CFR 50.36, which stated certain technical requirements may be relocated from the Technical Specifications (T/S) to other licensee-controlled documents, Atomic Alchemy will develop a Technical Requirements Manual (TRM) to centralize the requirements relocated from the T/S and to ensure the necessary administrative controls are applied to these requirements. The requirements in the TRM are considered part of the Atomic Alchemy licensing basis (a part of the SAR) and are to be treated as such. Like the SAR, changes to the TRM will be controlled under 10 CFR 50.59.

The NRC had determined that programmatic controls can be implemented in the Administrative Controls section of the Technical Specifications to satisfy existing regulatory requirements for Radiological Effluent Technical Specifications (RETS). Atomic Alchemy will voluntarily choose to implement the provision of Generic Letter 89-01, which allows the RETS to be removed from the main body of the Technical Specifications and placed in an Offsite Dose Calculation Manual (ODCM) in the administrative portion of the T/S. The Atomic Alchemy ODCM will be developed based on the Standard

[12] The Atomic Alchemy Title 10 Part 50 construction and operating licenses' approach will be addressed in a separate position paper.
[13] This policy statement was subsequently codified by changes to Section 36 of Part 50 of Title 10 of the *Code of Federal Regulations* (10 CFR 50.36) (see also 60 FR 36953, July 16, 1995).

Radiological Effluent Controls (SREC) compiled in NUREG-1301 modified as applicable to the NPUF facility.

3.5 Quality Assurance Program Description (QAPD)

Atomic Alchemy provided its QAPD to the NRC in Letter AAL-2020-003, "Atomic Alchemy Versatile Isotope Production Reactor Quality Assurance Program Description" Agencywide Documents Access and Management System (ADAMS) Accession No. ML20290A978, dated October 16, 2020. The Atomic Alchemy Quality Assurance plan is based on NQA-1-2017. Based on the complexity of the design of the Atomic Alchemy facility (multiple site nuclear non-power reactors; staged construction; multiple radiological processes; and 10 CFR Part 50 (and potentially 10 CFR Part 70) licenses, it was concluded by management that the Atomic Alchemy Quality Assurance Program should exceed the minimum requirements outlined for test and research reactors in NUREG-1537, Part 1, (ANSI/ANS-15.8) for the design, procurement, fabrication, construction, testing, and operation of the Atomic Alchemy facility.

3.6 Design Configuration Control

The Atomic Alchemy Current Licensing Basis (CLB) will include compliance with the NPUF applicable NRC regulations contained in Title 10, Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73, 100, and appendices thereto; orders; license conditions; approved exemptions; commitments; technical specifications; technical requirements manual; and offsite dose calculation manual. It will also include the plant specific design-basis information defined in 10 CFR 50.2 as documented in the most recent SAR, along with applicable requirements of 10 CFR 71, and the NRC Safety Evaluation Reports.

Configuration control of the CLB, and control of the overall design information, safety information, and records of modifications (both temporary and permanent) that might impact the performance of safety related SSCs or items relied on for safety (IROFS[14]) will be maintained in an Enterprise Data Management System (EDMS), all P&ID diagrams, 3D models, isometric drawings, Certified for Construction (CFC) design drawings will be maintained in a Plant Design Management System (PDMS)[15]. Atomic Alchemy will also explore the potential design, training, operations, and maintenance benefits of creating a digital twin[16] of its NPUF.

Though not required by regulations, a Design Basis Document (DBD) program will develop DBD packages for each safety related system. Each DBD package will include a system overview, boundaries, interlocks, interfaces, design background, diagrams, vendor information, line lists, component lists, component basic requirements, design calculations, parameters, attributes, design margins, accident analysis, and respective CLB requirements.

3.7 Off-Site Modular Construction (OSMC)

While the Atomic Alchemy NPUF uses a module design, this does not mean that the majority of these module buildings are engineered, fabricated, and/or tested offsite and subsequently delivered to the

[14] Items Relied On For Safety (IROFS) are treated as safety related in the Atomic Alchemy CLB.
[15] AVEVA PDMS will soon be phased out and replaced with AVEVA E3D.
[16] A digital twin is a virtual model designed to accurately reflect a physical object.

construction site for final assembly. Atomic Alchemy will not employ a large scale transfer of stick-built construction efforts from the jobsite to offsite fabrication shops. Materials required for fabricating modules offsite have to be procured much earlier and maintained in storage longer than necessary for conventional stick-build construction.

The Atomic Alchemy modular buildings are only considered modular from the point of view that each building shares a minimum number of systems and interfaces with other buildings, and they are easily isolated from each other during transient event scenarios. Instead, the use of modularity implies that the facility can be constructed in parts. The costs in fabricating and analyzing large modular type building mechanical structures for transportation and assembly on-site outweigh the benefits from remotely constructing them[17] that way.

Atomic Alchemy will use some factory-based manufacturing for specific components to improve quality since several major components and assemblies can be simultaneously fabricated and tested in the factory and then shipped to the construction site (e.g., prestressed concrete floor slabs, steel rebar assemblies, structural steel modules, and prefabricated wall sections). Additionally, some vendors will supply their products as fully assembled and tested skid packages, this would include items such as the CRDM, fuel handling machines, radioisotope process hot cells, silicon doping handling machines, radwaste vitrification and/or solidification hot cell packaged units, radwaste storage tanks, off-gas processing packaged units, makeup water tanks & pumps, tritium makeup and recovery skids, chemical volume & control tanks and pumps, charcoal filtration beds, etc.

3.8 Construction Accident Preventative Design Features

The A/E construction consortium partner will be responsible for developing the Construction Hazards Analysis (CHA) for each phase of construction. The A/E consortium design engineering partner will utilize a systematic approach for dealing with potential safety risks in the design, planning, and preparation stages known as Construction Hazards Prevention through Design (CHPtD).

The construction management team will establish safety, construction, operations, management, environmental and sustainability Key Performance Indicators (KPIs) in a performance matrix that targets the safe achievement of construction goals. Together with the Atomic Alchemy Oversight Program, and Corrective Actions Program (CAP) any potential emerging accident precursors and/or cross cutting issues will be identified and corrected.

Specific construction programs and procedures will be developed for protection of the site from the inclement weather and other external conditions after the completion of work to maintain it in the necessary environment. Construction personnel will be indoctrinated with adequate site in-processing, fitness for duty, site orientation and other appropriate training. A safety culture will be established at all levels among the construction personnel involved from the early stages of the project with the Atomic Alchemy Safety Conscious Work Environment program. Key best practices such as the use of STAR (Stop, Think, Act, Review) will be implemented.

[17] See lessons learned from the Westinghouse AP1000 modular construction approach.

The Atomic Alchemy construction team will develop accident preventative strategies which will include the following elements:

a. Creating a management work environment fostering good safety and health practices
b. Sufficient safety training for all employees
c. Effective communication and cooperation between craft and engineering
d. Effective construction site walk arounds and safety inspections
e. Maintenance of craft equipment and tools in good working condition
f. Good development of pre-task /pre-job planning focusing on all aspects
g. Effective use of protective clothing and gear
h. Alcohol and substance abuse programs
i. Effective use of the Corrective Actions program in identifying potential accident conditions before they occur

3.9 Construction Accident Mitigative Design Features

When accidents occur, effective plans are necessary to mitigate the extent of them. The majority of construction accidents are initiated by the following root causes:

a. Negligence on the part of a contractor
b. Failure to comply with OSHA regulations
c. Inadequate coordination and communication at various levels in the field or between management, engineering, and craft with regards to emergent issues
d. Inadequate training, experience, or knowledge of craft personnel
e. Inadequate design methodology for construction evolutions
f. Failures involving malfunctioning equipment
g. Inadequately written procedures
h. Failure to adhere to written procedures
i. Failures involving changes to the environment
j. Inadequate pre-job and post job briefs

The best practice to mitigate an accident is to prevent its initial occurrence, as described in the previous section, Atomic Alchemy's is committed to achieving the goal of zero construction incidents.

The Atomic Alchemy Fire Brigade teams will respond to all construction fire and personnel injury related incidents. The size and scope of a fire brigade team will be determined by the Fire Hazards Analysis (FHA). The Fire Protection Plan is addressed in another section of this position paper.

The construction site will use a wide variety of radio frequencies that could possibly interfere with the operating facility. The Atomic Alchemy Electromagnetic Compatibility and Radio Frequency (EMC/RFI) Program, an NQA-1 program will be used to evaluate and address any potential interferences.

Construction related electrical site utilities, switchgears, transformers, backup electrical systems will not be shared with the operating facility, isolation design features will be incorporated into the overall construction site electric utility plan. Other related service utilities like service water, instrument air, compressed air etc. are also not shared with the operating facility.

The Atomic Alchemy facility design incorporates features that increase the reliability and effectiveness of SSC's under degraded conditions are incorporated into the design and engineering of the facility, these features are based on the application of industry design and operating experience to mitigate the effects of accidents, therefore the likelihood of the operating facility systems, structures or components impacting the construction will be greatly decreased. A more in-depth discussion of the potential of operating facility accidents might impact the construction area will be presented in another section of this position paper.

3.10 Lessons Learned from the Westinghouse AP1000 Modular Design Construction Approach

To provide quick and affordable construction methods, the Westinghouse ALWR AP1000 utilized a modular construction design technique. The major construction of piping and mechanical/electrical components were designed to be shipped via barge, railcar, and trucks and were fabricated to be easily assembled. A typical sub-module weighed about 10 metric tons, while others weighed as much as 300 metric tons. The Westinghouse AP1000 design utilized 122 structural, 55 mechanical equipment, and 154 piping modules that were fabricated offsite and transported to the construction site for assembly.

Some of the problems encountered by this methodology was the necessity of requiring very heavy lift (VHL) construction cranes for lifting and setting these modules in place on the construction site for nearly the entire duration of the construction project. This created much greater risks during the assembly processes. Other problems arose due to ongoing engineering and field design changes, for example, locations of pipe support embedment plates needed to be removed or relocated on the module due to piping design changes. Some late identified optimal safety related design changes were not implemented simply due to the module already being fabricated and enroute to the construction site. Fabrication tolerances of various portions of the modules were more critical to the final layout and increased the costs associated with developing and maintaining them.

Perhaps the costliest problem encountered was the amount of additional stress analyses that were needed to be performed, and the additional steel trusses that were needed to be added as part of the mechanical and piping modules just to make them rugged enough for shipping and handling, for transportation, as well as for assembly on-site. Steel supports that were only necessary for transportation and/or lifting were left in place which greatly complicated maintenance, operations, testing, and inspections. The costs and time required for removing these practically eliminated the advantages of this constructing them by this method.

Atomic Alchemy's modular phased construction philosophy will avoid these drawbacks by early identification of these lessons learned with the comprehensive constructability review of the entire facility and the phased construction approach as well as creating a solid consortium partnership with A/E design and construction companies with proven track records of designing, building, and managing nuclear or heavy industrial construction projects.

4.0 THE ATOMIC ALCHEMY PHASED CONSTRUCTION PLAN

Atomic Alchemy will develop a consortium of engineering, procurement, and construction (EPC) partners, these will include a design engineering, architect engineer (A/E), and a construction architect engineer and an EPC to act as owners' oversight. This integrated engineering, procurement and construction approach will increase cost certainty and minimize scheduling problems. Both the design and the construction A/E consortium partners are selected based on experience and proven technical capability in designing and overseeing nuclear construction projects or industrial projects of similar scope and complexity.

Seismic Category I building structures of the Atomic Alchemy facility consist of the reactor confinement modules (RCM), reactor auxiliary modules (RAM), target fabrication modules (MTM), radioisotope process production modules (PPM), radwaste modules (RWM), the administration service module (ASM), and the service module (SRM) Buildings (see Figure 17.01). These structures are founded on a common base mat and are collectively known as the nuclear island or nuclear island structures. Seismic analysis of the nuclear island will be provided in SAR Chapter 3, Appendix G. The seismic analysis of the nuclear island will include accounting for the various stages of phased construction work and be detailed in the SAR.

A non-seismic shipping and receiving module (SRM) would complement each radioisotope process production module. A non-seismic diesel generator module (DGM) building is located on-site adjacent to the nuclear island.

The Atomic Alchemy nuclear island will consist of multiple distinct seismic Category I structures (erected in phases) founded on a common base mat. The reactor confinement and reactor auxiliary modules are coupled and monolithically constructed with reinforced concrete and considered one structure. The radioisotope production, target fabrication, and radwaste modules are likewise monolithically constructed and considered one structure. The administration service module building is considered one structure unto itself.

The construction of the Atomic Alchemy NPUF will occur in three phases that would be carried out over the course of 96 months. The tentative schedule for beginning Phase 1 construction would be immediately after receipt of the approved NRC construction permit (assumed approximately mid 2024). Construction of Phase 1 should take approximately 30 months. Operations are tentatively forecast to begin upon receipt of the approved NRC operating license in early 2027. Phase 2 construction could commence in early 2028 and take approximately 15 months, allowing some time interval for operations and re-evaluating production output and world-wide demand, Phase 3 construction could then begin late 2029 and take approximately 24 months with a tentative completion by late 2031.

For purposes of this construction position paper each 'complex' of the module buildings are tentatively identified as follows:

<u>VIPR Modules:</u>
'Galactica' (RCM-1, RAM-1)
'Pegasus' (RCM-2, RAM-2)

'Prometheus' (RCM-3, RAM-3)
'Triton' (RCM-4, RAM-4)

Radioisotope Process Production Modules:
'Atlantia' (PPM-1, MTM-1, RWM-1, SRM-1)
'Pacifica' (PPM-2, MTM-2, RWM-2, SRM-2)

Administration & Service Module:
'Cerberus' (ASM-1)

Phase 3 Service Module
'Celestra' (SRM-1)

Non-Safety-Related Diesel Generators Module:
'Raptor' (DGM-1)

4.1 Pre-Construction Phase Activities

Prior to beginning actual site construction, the Atomic Alchemy consortium construction partner will assess the site conditions, begin initial surveying, develop the overall construction site layout design, and create the necessary construction design engineering drawings, and the design specifications. The consortium partner will also be responsible for developing the site housekeeping requirements[18], procurement specifications, and the construction schedules. The development of detailed procurement specifications to cover all downstream activities (e.g., bid evaluation, negotiations and contracting, contract management, administration, and procurement document handling) are a critical path in organizing the construction project.

Atomic Alchemy, in conjunction with the consortium partners will develop the Construction Site Security Plan, Emergency Plan, Fire Protection Plan, and the construction Quality Assurance Program Document (QAPD) for submittal to the NRC for approval prior to initiating field work. These will be discussed in greater detail in later sections of this paper.

The construction consortium partner will characterize the site before construction begins to assess the impact that the facility will have on the site hydrogeology following construction. The site configuration prior to construction will also be evaluated for preventing the offsite migration of radionuclides via any unmonitored pathways that might develop as part of the construction process. This evaluation will identify any additional potential release mechanisms, release scenarios, and possible location of contaminant releases.

The necessary earthwork, roadwork, grading, storm drainage, culverts, above and underground electric utilities (both for construction and the permanent facility), existing and new underground water and sewer systems, stripped topsoil stockpile storage, concrete batch plant, aggregate storage, heavy equipment, warehouses, fabrication shops, security fencing, construction site offices, etc. must all be developed and arranged before actual construction begins.

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[18] Construction housekeeping requirements will meet NQA-1-2017, Part II, Subpart 2.3, "Quality Assurance Requirements for Housekeeping at Nuclear Facilities"

4.2 Phase 1[19]

The nuclear island base mat for Phase 1 and Phase 2 will be formed as part of the Phase 1 construction process. Computers will model and analyze the base mat seismic responses for the different phases of construction which will be included in the SAR.

The initial Phase 1 plan will be to construct one radioisotope process module (Atlantia) and its support module buildings along with one reactor module (Galactica) with its accompanying reactor auxiliary module building and the administration and service module building (Cerberus). This will support the initial production of radioisotopes processed in the reactor. Each radioisotope process module can support a quantity of irradiated radioisotopes from up to 2 reactors. Phase 1 construction would also include the non-safety-related diesel generator module (Raptor).

The Cerberus module will be designed and then constructed in its final four (4) VIPR / two (2) radioisotope process plant configuration. Provisions for staffing, equipment, testing, health physics, maintenance etc. for the full site staff will be included as part of Phase 1 construction. The Cerberus module I&C architecture will be designed and installed to easily interface with the additional instrumentation that will be required when the other modules are being constructed and tested. Very little future modifications will be required in the Administration and Service Module building to implement the other two phases. Administrative control programs would be used to maintain the functionality of the partitioned "designed for future system and components interfaces" while they are dormant.

4.3 Phase 2

The second phase would be to construct the second complimentary reactor confinement module (Pegasus) and its auxiliary module building to the initially constructed radioisotope process production module (Atlantia). Upon completion of this phase, the Atlantia complex would now be operating at its maximum capacity to process radioisotopes. [

]PROP

4.4 Phase 3

The third and final phase of the Atomic Alchemy project begins by completing the nuclear island base mat. Additional computer models will be created to analyze the base mat seismic responses for this final phase of construction based on "as-built" data. After that, the construction of the second radioisotope process production module (Pacifica) and its respective support modules along with its compliment of two reactor confinement/auxiliary modules (Prometheus and Triton respectively) and its support service module building (Celestra) begins.

The two radioisotope process production module complexes will be designed so that they can interface with any of the four operating reactor complexes.

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[19] Upon completion of the ITP, all necessary requirements of Title 10, part 50.57 will have been satisfied, the Atlantia, Galactica, Raptor and Cerberus Modules will be capable of independent, and indefinite operation without the necessity of completing any further Phase 2 or Phase 3 construction.

5.0 DESIGN FEATURES OF SAFETY RELATED SYSTEMS

Facility safety design features increase the reliability and effectiveness of SSC's under degraded conditions; application of industry design and operating experience is used to mitigate the effects of accidents.

5.1 Passive Designed Safety Systems

Passive designed systems provide facility safety and protect capital investment. They establish and maintain VIPR core cooling and confinement integrity indefinitely, with no operator actions and no AC power support requirements. The passive systems meet the single failure criteria. The Atomic Alchemy VIPR passive safety systems are considerably simpler than typical ALWR safety systems. They contain significantly fewer components, which reduces the required Technical Specification LCOs, surveillance testing, and maintenance. The Atomic Alchemy passive safety systems do not require any primary reactor coolant fluids to leave the confinement module building following a postulated transient.

The Atomic Alchemy ultimate heat sink does not rely on any external natural sources of water. Systems like Diesel Generator, HVAC[20], Cooling Water, AC power are also not required to be safety related in order to maintain both the NPR and radioisotope processes in a safe shutdown mode. FSAR Chapter 15 analysis will demonstrate that for all design basis accident transients the reactor core remains covered by water, this includes SB and LB LOCA transients.

The Atomic Alchemy's fission products control strategy also does not require on-site or offsite A/C power and does not depend on active systems to remove airborne particulates or elemental iodine from the confinement atmospheres of the Reactor Module, Radioisotope Production Process Module, Target Production Module or Radwaste Module following a postulated accident in any of these building modules. [

PROP While the Atomic Alchemy reactor and process modules employ active air filtration systems, they are not required for any post-accident scenarios.

6.0 DESIGN FEATURES OF SHARED SAFETY AND NON-SAFETY-RELATED SYSTEMS

The Atomic Alchemy NPUF facility meets the Atomic Alchemy Principal Design Criterion PDC 5 which is based in part on Part 50 Appendix A, GDC 5 which addresses the sharing of safety related systems and components with respect to its NPR reactors and their sub-systems. There are no Part 70.64 similar requirements with respect to process facilities and Atomic Alchemy does not apply its PDC 5 criterion to the radioisotope production process related SSC's (e.g., the SSC's located in the radioisotope

[20] The Atomic Alchemy Control Room Emergency Habitability System (CRE) and the Control Room Emergency Ventilation and Filtration System (CRF) are the only designated safety related HVAC systems.

production, radwaste or target production modules) all of which may share some SSC's that perform safety related or important to safety functions.

The Atomic Alchemy non-safety-related shared systems are designed for operational reliability and availability to minimize restrictions on VIPR operating configurations during normal modes of operation. The shared systems include design features such as redundancy, spare capacity, isolation, and consideration of system interfaces. These features minimize the necessity of taking an operating VIPR out-of-service for testing configurations of any new construction activities.

6.1 Shared Safety Systems Interactions and Interfaces

The Atomic Alchemy NPR light-water pools (which also contains each reactor's spent fuel) shares a common light-water radioisotope transfer canal pool (TTW) system with one other NPR core light-water pool. For conservatism, the TTW system will be designed so that it can also function as an "emergency core cooling" type of system, identified by Atomic Alchemy as the safety related reactor Decay Heat Removal system (DHR) which will be an additional source of water for both of the NPR light-water pools it interfaces with.

In the SAR Chapter 15 analysis, an emergency core cooling system will not be required for any DBE scenario, the core of each NPR will always remain covered by water even for any postulated LOCA transients. This DHR system will be designed and implemented for conservatism only, thus it meets Atomic Alchemy's PDC 5. The sharing of this safety related DHR makeup water will not impair the capability of either NPR's other safety related systems to perform their intended safety functions within their required mission times.

Each NPR will have their own dedicated DC 1E UPS system located in the reactor auxiliary module building of each reactor. The Atomic Alchemy DC 1E UPS system will be shared for the Radioisotope Production Processes, which includes augmented design provisions for sharing 1E power across Radioisotope and Radwaste Processes that prevents adverse interactions and the introduction of other failures of systems that are required to ensure a safe shutdown of any radioisotope, target production, or radwaste ongoing process.

The electrical and I&C systems for the radioisotope production process, target production, and radwaste module buildings may feature some shared electrical and I&C safety related systems. Although shared, the design will include a number of independent divisions to be designed for depth, diversity, and redundancy which will allow for out of service and testing.

Except for the DHR system, reactor safety related electrical, I&C, HVAC, primary coolant, secondary coolant etc. systems are module specific and function independently of the other VIPRs which minimizes adverse reactions from construction and startup testing activities.

6.2 Shared Non-Safety Systems Interactions and Interfaces

These shared non-safety-related systems are designed with conservative assumptions in considering radioactive releases and include redundancy and isolation design features for out of service and testing, which will prevent the uncontrolled release of radioactivity to the environment.

Non-safety-related AC power is not relied upon to maintain the core and spent fuel cooling, confinement module integrity, radioisotope module integrity, or radwaste module integrity. Although not relied on for facility safety-related functions, the AC power systems are designed with reliability considerations, including independence, redundancy, and testability.

7.0 ENHANCED CONSTRUCTION PROJECT FEATURES

7.1 Front End Planning (FEP) and Construction Site Layout

Front End Planning (FEP), or pre-project planning, are the activities undertaken at the beginning of a project to ensure that the project is properly defined, planned, and estimated so that an informed decision can be made as to its viability and readiness to proceed. Good site-based management and layout planning can make significant improvements in the safety, and effective cost and time savings during the construction process. Construction site layout involves identifying, sizing, and placing temporary construction facilities within the boundaries of construction site located within the owner controlled area. These temporary facilities range from simple laydown areas to site security, electrical power sources, lighting, quality controlled testing and storage warehouses, fabrication shops, maintenance shops, on-site concrete batch plant with aggregate storage piles, cement silos, and temporary engineering offices and support facilities as well as construction personnel parking.

Layout planning for reutilization of the construction equipment and facilities with a minimum loss for the same functions for the next construction phase is also a critical part of the planning.

The design A/E consortium partner will complete the final design engineering of the facility. The construction A/E consortium partner will provide the overall construction management for the facility. The design engineering partner will also provide the owner's representation and oversight during the construction phases. Other design and construction activities will be contracted to qualified suppliers of such services. Atomic Alchemy's construction organization will be provided in SAR Chapter 13, Appendix F. Construction milestones will also be described in SAR Chapter 13.

7.2 Project Milestone, Earned Value, and Requirements Management Tools

Project control, monitoring and oversight involve analyzing information to understand, influence and predict important project objectives such as resources, cost, and time schedule. This makes effective project management, planning and decision making possible. Project milestones alone have limitations to their usefulness. They usually show progress only on the critical path and may ignore non-critical activities.

Earned Value Management (EVM) integrates the project's scope, cost and schedule baselines and compares them to the project's actual performance. EVM develops key dimensions for each work package and control account. The technique is most effective when individual items are cost estimated and scheduled appropriately and measures of completeness for long duration items are formalized. EVM is based on the completed work and utilized to review whether a project (or significant parts of a project) is at, behind, or ahead of schedule, or is at, above, or below their respective planned budget.

Requirements Management (RM) is the process of documenting, analyzing, tracing, prioritizing, and agreeing on requirements and then controlling change and communicating to relevant stakeholders. It represents a method of implementing the quality control standards of the Atomic Alchemy construction consortium for continuous quality assurance and quality control process throughout the project.

The Atomic Alchemy A/E construction consortium partner will take advantage of these project management tools in developing the construction plan.

7.3 Importance of a Proven Design, and Proven Equipment Supply Chain Vendors

The Atomic Alchemy facility minimizes the use of First-of-a-Kind (FOAK) designed systems and components that may require specialized manufacturing, construction, regulatory approval, or startup testing. Safety related system and component design will be based on a passive safety concept, that utilizes approved nuclear industry and commercial grade equipment and components. Likewise, an important cornerstone in the construction plan is the reliance on proven experienced supply chain vendors and manufacturers, as well as using the latest[21] approved industry codes and standards.

7.4 Organizational Project Management Maturity Model (OPM3)

The Atomic Alchemy Construction project organization will systematically research and implement best practices in all areas of the project. A large nuclear construction project complexity quickly escalates once vendors and support organizations are contracted. These organizations can each have their own way of managing their deliverables. Atomic Alchemy's construction A/E partner will ensure that a construction project management system is planned and in place at an early stage and that it fully integrates with the overall management system of Atomic Alchemy and its other consortium partners. Vendors and contractors can utilize and adapt as necessary to the consortium organization's pre-established corporate construction management processes.

The project management institute (PMI) provides a framework called the Organizational Project Management Maturity Model (OPM3) that offers a comprehensive list of construction management best practices. Best practices improve performance not only in terms of cost, schedule, and safety. They can also increase the consistency and predictability of project performance. These proven construction management tools will be utilized in creating the Atomic Alchemy consortium construction project management plan.

[21] Atomic Alchemy intends to comply with the requirements of the specified revisions of industry codes and standards that have been incorporated by reference into the Title 10 regulations or endorsed in the regulatory guides. In some instances, Atomic Alchemy may choose to comply with a later revision. In these instances, Atomic Alchemy will either submit an alternative under 10 CFR 50.55a(z) or in some cases it may be discovered that the NRC endorsed a later version in a SER for a ALWR Part 52 application or for a WCAP.

7.5 Key Design and Construction Optimization Features

Documentation

Quality documentation will be a critical aspect of construction. Atomic Alchemy's documentation requirements for suppliers will be developed by their construction A/E consortium partner and based on regulatory requirements, safety classifications, and other pertinent information required for operations. Suppliers must provide the necessary documentation that proves how regulatory and/or industry code requirements have been met, along with documentation that satisfies the operational functionality and mission requirements. The A/E partner will work with suppliers to eliminate extraneous information and consolidate the required information. This process will reduce the number of quality records that will be required to be prepared, reviewed, and maintained without any loss of quality in the data packages.

Documentation will also include maintaining labor control, material control, and quality control. Individual construction employee qualifications are required to be up to date for such things as welding and QA inspections. Atomic Alchemy utilizes QAPD level programs such as Certified Material Test Reports, (CMTR), Special Nuclear Material Accounting and Control Program, Materials, Equipment, and Parts List (MEPL) Program, Receipt Inspection Program, and Commercial Grade Dedication Program to ensure the facility will be constructed as designed.

Integrated & Advanced Work Packages

Work packages are a complete set of documentation, in paper or electronic form, that is needed by field trades to perform a specific work activity. Work package assessment is the process of reviewing approved design and material related data associated with the necessary activity and translating it into a format by which the work can be efficiently scheduled, estimated, and safely and predictably executed. As part of the advanced work package, a process will be in place for addressing design engineering changes and any necessary field engineering changes in a timely manner and will maintain configuration control of all associated impacted work packages. The project manager or an approved delegate can typically approve some changes, while other significant changes will be approved by Atomic Alchemy management.

Single Point Accountability

This basic management concept was best summed up at the dawn of nuclear plant construction, in the early 1970s, by Stone & Webster Engineers and Constructors, that "the first baseman plays first base." He does not attempt to play any other positions that have not been assigned to him by the coach. A Single point accountability is a simple two point concept. Point one, that the person who has the authority to delegate something will hold one single individual accountable for the results. Point two, the individual who is closest to the action should have the accountability and authority to do the work because they have the best information needed to make the best decisions.

Atomic Alchemy and its A/E construction consortium partner will implement this project management tool effectively to ensure that all vendors and suppliers understand the scope of work, the deliverables, and the required delivery dates.

Value Engineering

Value engineering (VE) refers to systematic approaches to ensure reasonable delivery of products and services by using an examination of the delivery function. Value is defined as the ratio of function to cost, or the purpose of achieving essential functions at the lowest life cycle cost consistent with required performance, quality, reliability, and safety. The principle of VE will be utilized in:

a. Identifying the main elements of construction.
b. Analyzing the technical and functional requirements of those elements.
c. Developing and accessing potential primary and secondary sources for delivering those elements.
d. Developing solutions for transportation, storage, assembly, and testing those elements.

Design to Cost

Design to cost (DTC) is a cost management technique that can be used in early construction project development. It will establish cost goals that are essentially a separate project requirement. DTC will evaluate the removal of unnecessary design features from a proposed component or system where the project cost goals are also an important factor without reducing its impact to safety.

7.6 Primary Innovative Construction Techniques

The discipline of construction management includes significant planning and control of the construction site infrastructure and layout as well as taking advantage of the latest proven construction best practices.

The Atomic Alchemy facility construction will be enhanced by its modular design and open top construction techniques. This construction method promotes installation activities that are carried out in parallel. Construction sequencing and installation logic of major large mechanical equipment will be effectively coordinated.

Integrated project scheduling and emerging issue management processes will ensure efficiency and agility and promote continuous improvement so that the Atomic Alchemy A/E construction partner can meet deliverables and commitments while prioritizing Atomic Alchemy resources.

All-Weather and Around-The-Clock Construction

][PROP] The first priority of the construction team will be to provide permanent and temporary site drainage designed that the construction site is 'waterproofed' and/or protected against regional natural phenomenon in order to quickly recover after inclement weather and not subject the construction schedule to unnecessary delays.

The influence of the weather on construction activities is often a prime reason for delays in a construction schedule. Some of the advanced construction methods to be used by Atomic Alchemy include “open top” construction which require the construction area to be open in order to lift in modules/heavy components. To assure that work can be conducted continually, an ‘all-weather’ construction technique must also be applied to the open top module buildings to shield the worksite from extreme weather conditions.

Utilizing an all-weather method, the side of the open module building is protected by temporary pavilions attached around the outside to the steel frame. A temporary, movable roof is also installed to cover the top of the module building. This all-weather construction method provides an improved environment for concrete pouring, curing, and welding. It also serves to protect equipment already installed through the open top construction. To optimize the schedule, the all-weather construction method will require detailed planning and engineering. The pavilion temporary steel framing will be coordinated with the permanent structural components

Advanced Excavation Methods

To minimize the impact on the operational facility the construction contractor can employ a variety of new advanced excavation methods such as precision line blasting and chemical foam expansion for breaking rock which has the following advantages:

a. Minimal fly rock, reducing the protection requirements from the blasting
b. Minimal noise and overpressure
c. Minimal vibrations
d. Minimal interruptions to the other construction site operations
e. Minimizes the necessary quantities of on-site explosives

Advanced Concrete Design & Installation Methods

Improvements in the concrete mixes, concrete curing, foundation construction, concrete re-enforcement, placement equipment and concrete batching operations have made single monolithic base mat placement pour more feasible and easier to manage. Advancements in concrete mix technologies has created the availability of concrete mixes with improved strengths, workability, and corrosion resistance.

The Atomic Alchemy A/E design consortium partner will be responsible for developing and qualifying the concrete fabrication and installation processes to meet the design requirements specified by the project. Types of advanced concrete work that can be utilized include high workability concrete, self-consolidating concrete (SCC), fiber-reinforced concrete, self-leveling concrete, using pre-cast concrete and prefabricated rebar assemblies. Some advanced concrete wall installation methods include slip forming and jump forming. The major advantage of slip forming is that it results in a significant shorter schedule.

The Reactor pool liners will be prefabricated in a shop and installed in ring segments. Automated methods for installing rebar is a potential alternative approach that has recently been used to speed up the installation of rebar and provide consistent results for reinforced concrete structures. The following advantages are gained by using these proven advanced structural techniques:

a. Shorter duration of construction
b. Less labor intensive
c. Easier placement
d. Reduced personnel power where SCC and self-levelling concrete are used
e. Improved control of the concrete quality and consistency

Advanced Structural Steel Design, Fabrication and Erection Methods

Typically, site construction management is responsible for the overall installation of structural steel. The structural steel design is provided to a steel fabrication subcontractor who is responsible for preparation of connection designs, erection methodology and shop drawings. The subcontractor is also responsible for assisting the erection of structural steel. The approval of the shop drawings and overall methodology is the responsibility of the A/E construction consortium partner.

The design of the Atomic Alchemy NPUF will be developed using 3-D PDMS[22] software by the A/E design consortium partner, this allows the steel fabrication subcontractor to extract the 3D structural steel models for use in an automated fabrication shop that can use lasers to control the tolerances. Some of the structural steel can be modularized and prefabricated off-site. Another advanced structural steel methodology that may be considered by the A/E design consortium partner is the use of Buckling Restrained Braces (BRBs) versus traditional concentric steel braces. The use of BRBs exceed all American Institute of Steel Construction (AISC) provisions, and independent analysis has demonstrated that incorporating BRBs into a construction project of this size can considerably reduce building costs, and when seismic energy is dissipated throughout a BRB structural steel system, deformation of beams and columns can also be minimized. The following advantages are gained by using these proven advanced structural steel fabrication and erection techniques:

a. Less steel, welding and crane time used during erection.
b. Improved fabrication schedule.
c. Improved quality control.
d. Improved tolerances.
e. Improved seismic response (BRB).

[22] AVEVA PDMS will soon be phased out and replaced with AVEVA E3D

Advanced Welding Design & Practices

The most common process in the construction of a large facility is welding. These processes include structural welds used to connect structural beams and rebar; pressure welds used to fabricate pressurized components and weld cladding to deposit materials on the surface of another material. Advanced welding techniques include using lasers for measuring and alignment, eliminating as many welds as possible, for example by utilizing piping bends instead of welded fittings, moving a significant amount of welding to the shop from the field, and taking advantage of robotic and automated welding and inspection. Algorithms can be used for welding quality control. Atomic Alchemy will take advantage of these advanced welding techniques as part of their overall QAPD level welding programs.

Advanced Mechanical Piping Design and Installation Methods

The Atomic Alchemy 3-D design computer model will be embedded with and linked to vital design information such as ASME/ANSI codes, industry standards, P&ID diagrams, and the design specifications. This advanced design feature will allow the easy extraction of Certified For Construction (CFC) isometric fabrication drawings complete with a Bill of Materials to be used by the different piping and ductwork fabrication shops. Similar to the fabrication of structural steel, piping and ductwork spool pieces can be manufactured with laser quality precision.

Piping bends will be used in ASME Class 1 and 2 piping spools to the extent practical in lieu of welded fittings to minimize welding and ASME ISI/IST inspections.

The 3-D facility model can also be linked to an Enterprise Data Management System (EDMS) for construction schedules; ductwork and piping spool section and valves' inventory control; QA/QC receipt inspection; pre-operational testing requirements; and system turnover. The 3-D model will also be used for interference checks between the various disciplines, checked for maintenance access, ISI/IST pre-service inspectability, and overall operational access.

Advanced Quality Control Methods

The overall responsibility for the success of the Atomic Alchemy construction project is provided by a single entity, the A/E construction consortium partner. Using advanced information management techniques, including planning and database software, they can maintain effective control of project information that will fully integrate design, procurement, construction, and testing activities. Having the planning centrally located by a single entity improves efficiency such as managing testing activities to reduce the impact on construction sequencing and utilizing current types of construction techniques.

Digital radiography and ultrasonic imaging are improvements in the QA/QC field. These images are high quality and immediately available for review and acceptance. The digital images will be stored in digital file format that can be stored, copied, and shared without degradation. The Atomic Alchemy QAPD-level record programs include provisions for the generation, distribution, use, maintenance, storage, and disposition of electronic records.

Advanced QC methods in video and other imaging techniques, including miniaturization and remote manipulation, minimizes construction hold points in congested areas of construction for visual inspections. Foreign material exclusion is another area of visual inspection that is aided by advanced imaging techniques.

Advanced Electrical, Instrumentation and Control (I&C) Design, and Installation Methods

Significant advances have been made in I&C technology. Technology has evolved from the analog control to modern Distributed Control Systems (DCSs) utilizing computer laptop operator interfaces and new control algorithms based on modern microprocessor technology. Atomic Alchemy's NPUF design will incorporate digital software, digital I&C controls, and commercial grade dedication components in the design of their I&C architecture. Software engineering, design, development, acquisition, testing, and control requirements identified in the Atomic Alchemy QAPD which is based on NQA-1-2017, this establishes the necessary quality standards for safety related systems and components.

Advances in Integrated Circuit (IC) technologies can affect safety and improve operating margins, these include radiation-hardened ICs and System-on-a-Chip (SoC) devices. The potential impact toward facilitating smart sensors and sensor networks in reactor confinement and hot cell applications continues to be a valuable improvement in new technology. Advances in sensing devices that are immune to the contamination and thermo-mechanical response shifts that plague thermocouples and Resistance Thermometers Devices (RTD) improve operating and safety margins.

The installation of cables requires significant time and labor. The term "cable pulling" is used for the process of cable installation in electrical raceways. The advanced method of installing cables is in the use of computer software cable and raceway routing systems. This software is integrated into the 3-D PDMS[23] mechanical electrical design of the facility, this allows the cable tray and conduit subcontractor to extract the 3D models for use in an automated fabrication shop. Both the cable tray and their supports can be prefabricated as small modules in the shops, and then installed on-site. 3-D modeling of instrumentation, including tubing layouts, for congested areas will be utilized. This is especially useful for reactor core and hot cell monitoring systems and reactor protection systems.

The Atomic Alchemy facility wide Data Display and Processing Systems (IDD) will be designed with a fiber optic based backbone. Fiber optic cables systems can be qualified for use up to a maximum temperature of 150°F, with 100% humidity, and can be manufactured to withstand the effects of both local nominal radiation exposure and the radiation exposure postulated from the DBE. The following advantages are gained by using these proven advanced electrical design, fabrication, and installation techniques:

a. Reduction in the number of cables and supports.
b. Reduced man-hours for cable pulling and necessity for field routing.
c. Reduction in the overall cost of the cables.

[23] AVEVA PDMS will soon be phased out and replaced with AVEVA E3D

d. Reduction in the size of conduits because the total section of the cables can be decreased.
e. Improvement in the maintenance of components using plug-in connectors.
f. Improved quality of components.

7.7 Radiation Protection Design Features for Construction Activities

The Atomic Alchemy Radiation Protection Program will be a Technical Specification level program (T/S 5.6.5) which will be developed using NEI 07-03A, "Generic FSAR template guidance for radiation protection program description," and NEI 07-08A, Revision 0, "Generic FSAR template guidance for ensuring that occupational radiation exposures are as low as reasonably achievable (ALARA).

Atomic Alchemy will implement reactor and radioisotope process design and operating considerations to reduce personnel radiation exposures. These Phase 1 construction design features will minimize any potential exposures to construction personnel during Phases 2 and Phase 3. Some of the design features to accomplish this will include the following (for a complete list see FSAR Chapter 12, Section 12.1):

a) Locating equipment, instruments, and sampling stations that require routine maintenance, calibration, operation, or inspection in a manner that will promote ease of access and minimum required occupancy time in or through any radiation areas.
b) Designing, where practical, for transportation of equipment or components requiring service to a lower radiation area.
c) Designing labyrinth entrances to potential radioactive pump, equipment, radioisotope hot cells, Special Nuclear Material (SNM) feedstock storage areas, recycling and recovery areas, radioactive waste holding areas sources. Adequate space is provided in labyrinth entrances for easy access.
d) Highly radioactive components with minimal maintenance requirements will be located in completely enclosed or isolated compartments and will be provided with access via a shielded hatch, removable blocks, or they will be located below normal traffic areas in a cavity with the appropriately designed barriers.
e) Designing a means and adequate space for using movable shielding for sources within a service area, when required.
f) Administrative Controls will be developed to control entry and will include areas locked to limit access and alarms and signals that alert workers to prevent unauthorized entry into radiation areas and high radiation areas.
g) Designing ventilation air flow patterns from areas of lower radioactivity to areas of higher radioactivity.

For most of Phase 1 construction, radiation protection is not a consideration, as no SNM will be on-site during the first phase until initial fuel loading and start up testing begins on the reactor, at which point the Atomic Alchemy radiations programs will be in place. When Phase 2 construction begin the Atomic Alchemy radiation protection program procedures will be modified to be applicable to the construction areas as required.

Facility areas will be categorized into radiation zones according to design basis radiation levels and anticipated personnel occupancy with consideration given toward maintaining personnel exposures ALARA and within the standards of 10 CFR 20. Rooms, corridors, piping chases, and other areas are evaluated for potential radiation sources during normal, shutdown, and emergency operations and for maintenance occupancy requirements. Each radiation zone defines the radiation level range expected in the zone. The radiation zone categories will be developed and the zoning for each Atomic Alchemy Module under normal conditions will be shown in the PSAR. The construction areas for all phases (inside the owner-controlled area) will be designated Radiation Zone RZ-0 (≤0.25 Mrem/hour), very low or no radiation sources, with unlimited occupancy.

During reactor operations, the reactor confinement module building, and the reactor auxiliary module building protects personnel occupying adjacent plant structures and outdoor construction areas from radiation originating in the reactor light-water pool and primary reactor coolant loop components. The concrete building walls will reduce radiation levels outside the reactor confinement, radioisotope process, and auxiliary module buildings to less than 0.25 Mrem/hr (RZ-0) from sources inside these operating modules, allowing for unlimited occupancy by construction personnel around the operational module buildings.

Atomic Alchemy will emphasize the training of all construction site personnel so that they are aware of the potential radiological hazards and of the necessary precautions and protective measures. All construction site personnel, who are working in a radiological controlled area or who may have necessity to enter such areas periodically, will have their occupational exposures assessed in accordance with the requirements of the radiation protection program which would include the use of Thermoluminescent Dosimeter (TLD) devices.

Atomic Alchemy and the A/E consortium design engineering partner will conduct preconstruction design reviews to evaluate the potential for offsite migration of radionuclides via any unmonitored pathways that might develop as part of the construction processes. This evaluation will identify the planned releases and any additional potential release mechanisms, release scenarios, and possible location of contaminant or gaseous releases that could impact the construction areas. Local area radiation detectors and alarms will be located around the construction area to monitor potential abnormal releases from the facility or the stack module.

In the unlikely event of a radiological DBE at the operating facility during construction activities, the construction area personnel will follow the Atomic Alchemy Emergency Plan. Elements of the plan will be augmented in the UFSAR to suit Phase 2 and Phase 3 construction activities. This will be further described in another section of this position paper.

7.8 Elements of the Site Layout Plan

Safety

Fire safety and prevention, proper protective clothing, good work practices, etc. are all promulgated through Atomic Alchemy's construction programs and procedures. Additional specific safety and construction protocols are implemented through the A/E Construction

Engineering Consortium partner's programs. See a detail description of the fire protection plan in another section of this position paper.

Accessibility & Security

Easy accessibility will minimize the chance of accidents and save time in maneuvering to arrive at and leave the project. Construction site security will be a subset of the Atomic Alchemy Security Plan submitted to the NRC for approval and implemented day-to-day under the A/E Construction Engineering consortium partner's programs. See a detail description of the security plan in another section of this position paper.

Location of Supporting Services e.g., generators, lighting, fabrication, maintenance, etc.

The temporary construction support facilities must be available and operable prior to the start of the construction schedule. A designated construction area will be developed for each phase of the Atomic Alchemy construction plan. Access to the construction area and between the construction area and the existing operational facility will be restricted. See the detailed description of the Security Plan in another section of this position paper.

The development of the concrete site batch plant, concrete testing laboratory, as well as a backup plant in close proximity, are critical paths for the construction plan along with indoor warehousing, outside storage, prefabrication and preassembly of modules laydown areas, and material staging areas.

An on-site fabrication shop will be necessary to support rework or to modify miscellaneous metals, pipe, tray, HVAC duct, reinforcing steel and embedments as required.

A crane study will be performed by the A/E construction consortium partner to determine the number and size of cranes required to support critical paths of construction and logic sequencing for planning 'maximum radius' of the crane's main location. Additionally, the construction management team will develop a Crane Usage Report that will be integrated into the overall critical path schedule of the project.

Support services like temporary backup generators, construction equipment fuel depot, and site lighting to permit night construction will be developed by the A/E construction consortium partner.

Inventory Control, Material Handling & Storage

Construction site materials management is a key construction process that will be established early on in the construction phase to ensure that quality programs and procedures are in place. The management of materials required to construct the Atomic Alchemy facility is vitally important to the procurement phase, to transportation to the site, to receipt inspection & temporary storage, to installation and turnover of completed systems while maintaining complete quality records during all these phases. Atomic Alchemy provides NQA-1 level programs including Procurement Document Control Program, Vendor Inspection Program, Commercial Grade Dedication Program, Receipt Inspection Program, Materials, Equipment, and

Parts List (MEPL) Program, and the Material Control and Accountability Program to facilitate these requirements.

8.0 SCREENING METHODOLOGY FOR THE IMPACT OF CONSTRUCTION ACCIDENTS ON MULTIPLE OPERATING MODULES

This section describes the methodology for assessing physical interactions between operating SSC's and those SSC's that are under construction under postulated Design Basis Event (DBE) conditions for the Atomic Alchemy Facility. Mechanisms that can cause damages on the construction site are analyzed in terms of their potential to propagate to SSC's in the operational modules. Initiators that may affect both construction activities and multiple operating modules by their definition, such as Loss of Off-site Power (LOOP) will also be analyzed for any additional potential unintentional consequences. Accident sequences that require random failures to occur in multiple construction evolutions in addition to the initiating accident component failure are not considered. The A/E construction consortium partner will analyze the impact on the operational SSCs as part of the overall site CHA.

Atomic Alchemy and its design engineering consortium partner will analyze internal and external accident sequences that impact existing operating modules which will then be described in FSAR Chapter 15. There are no DBE release scenarios that include radionuclide emissions from more than one VIPR or more than one radioisotope production process simultaneously. There are no Condition 1 or 2[24] transients in the operational modules that are postulated to impact any construction area related SSCs. Condition III and IV transients, as well as the BDBE have the potential to impact the phased construction areas. Under those circumstances the construction area personnel would follow the Atomic Alchemy Emergency Plan. See a detailed description of the application of the Emergency Plan to the construction area in another section of this position paper. BDBE transients for the operating SSCs will be addressed in FSAR Chapter 19. For the purpose of this section only transients occurring from Phases 2 and 3 construction activities and their subsequent impact on operating SSCs are evaluated.

8.1 Hazard Scoping Study

The A/E construction consortium partner will develop a Hazard Identification (HAZID) report which will identify potential hazards, determine potential consequences of the hazards, propose recommendations to eliminate, prevent, or mitigate hazards, and provide a well-defined basis for accident event screening as part of the subsequent formal Construction Hazards Analysis (CHA) assessment. Postulated Initiating Events (PIE) are categorized and grouped. All events with the potential for serious consequences and all events with a significant frequency of occurrence are considered in the PIE screening.

[24] ANSI 18.2 "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants" was superseded by ANS 51.1, "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants" which was subsequently withdrawn. Atomic Alchemy, however, continues to use the standard to define Condition I, II, III, and IV transients throughout the SAR per Regulatory Guide 1.70.

PIEs are evaluated across all operating modes (startup, normal, safe shutdown, and refueling) of the VIPRs. The initial conditions will assume a steady state with essential operational equipment functioning normally. Postulated PIEs taking place during plant operating transitional modes of negligibly short duration will be excluded from CHA (the shuffling of new or spent fuel however is not excluded from the analyses). In addition to the postulated initiating event itself, the loss of off-site power will be considered as an additional conservative assumption occurring at a time during the construction event that would have the most negative affect.

8.2 Deterministic Approach

The Objective of the deterministic approach is to established specific predetermined accident states for credible initiating construction accident events that are identified in the HAZID and demonstrate that safety related SSCs can continue to perform their design functions within their mission time reliably under these additional construction accident conditions and any potential radiological consequences will continue to meet regulatory requirements. The objective of the CHA is to ensure the safe operation of the facility during construction evolutions to a 95/95 level of probability and confidence.

The Deterministic Safety Analysis (DSA) will address best estimates based on evaluations of operating experience, engineering judgement and/or failure mode effects analyses plus an added quantified uncertainty (based on conservative assumptions) to develop realistic transients. DSA predicts the response of the operating facility to postulated initiating construction accident events, alone or in combination with additional postulated failures. PIE sequences are also evaluated for the possibility that a single construction related transient could simultaneously impact multiple VIPR or radioisotope process module systems, structures, or components.

Postulated initiating events will only include those failures (either initial or consequential) that have the potential to directly lead to challenging safety functions of the operating SSCs that can threaten the integrity of radionuclide barriers. This would include supporting systems whose failure leads to the activation of a reactor protection system. Systems that will be credited in deterministic analysis will be limited to the normal operating systems for that mode of operation, including planned operator actions that are performed during these operational modes. All safety related systems will be assumed to be operable for the mode of operation chosen for the PIE.

8.3 Acceptance Criteria

Acceptance criteria is developed to assist in judging the acceptability of the results of the DSA. For the construction transients' impact on the operating SSCs preliminarily, the only acceptance criteria will be the radiological consequences, that is, the determination that the integrity of the fission product barriers will be maintained against the accidental release of radioactive materials exceeding regulatory limits within an established acceptable margin.

Acceptance criteria will be related to the frequency of the PIEs. Situations that might occur frequently, will have an acceptance criteria that is more restrictive than those for less frequent events. The radiological acceptance criteria will be expressed as effective dose limits for the workers at the construction site and for members of the public in the vicinity of the construction site.

Additional technical acceptance criteria for the operating SSCs may be developed as part of the DSA. These would relate to parameter values of components such as temperature, pressure differences, concentration of gases, etc. For postulated initiating events occurring during shutdown modes or other maintenance activities with disabled trains or degraded integrity of any of the barriers, more restrictive criteria will be developed.

The conservative initial boundary conditions for acceptance criteria of technical parameter values will be selected from the Atomic Alchemy Technical Specification's operational limits and set point thresholds. In accordance with the single failure criterion, the single failure will be postulated in a system or component that leads to the greatest challenge to the safety systems.

Radiological acceptance criteria will include the habitability of the reactor control room, other types of evacuation routes and emergency response locations (i.e., fire brigade), and the areas used to move between them.

8.4 Uncertainty Analysis

Several methods for performing uncertainty analysis include:

a. The combined use of expert judgement, statistical techniques, and sensitivity studies
b. Use of data from scaled experiments
c. Use of bounding scenario calculations
d. Use of computer codes[25] for the DSA

The Atomic Alchemy consortium partner will assess the uncertainties with emphasis on the identification and separation of aleatory and epistemic [26] sources of uncertainty. In order to avoid "cliff edge effects,"[27] sensitivity studies may be performed to demonstrate when different assumptions are made about specific parameters with significant margins remaining.

8.5 Selection of Construction Postulated Initiating Events (PIE)

The list of construction postulated initiating events will be partially derived from large scale industrial construction experience feedback, including experience from nuclear power plant construction. The HAZID report will include failures of structures, systems, and components of construction equipment and newly installed reactor and radioisotope equipment undergoing startup testing, this will also include possible spurious actuation of systems. Also included will be failures initiated by operator errors, incomplete testing and maintenance operations and failures of structures, systems and components arising from internal and external hazards.

In addition to the set of construction postulated initiating failures and consequential failures, other external driven failures will be considered in CHA for conservatism. Some failures also may be added to

[25] All computer codes are evaluated through the Atomic Alchemy's Software Verification and Validation Program, an NQA-1 program.
[26] Aleatory uncertainty is uncertainty inherent in a phenomenon. Epistemic uncertainty is uncertainty attributable to incomplete knowledge about a phenomenon.
[27] The initiation of a severe abnormal condition caused by an abrupt transition from one state of a system, structure, or component to another state following a small deviation in a parameter value or a small variance in an input value.

bound a similar set of hazards to limit the number of analyses. Some events will be analyzed against multiple different acceptance criterion.

Postulated Initiating Events will be categorized by the following:

a. Low-complexity operational failures
b. Single failure electro-mechanical
c. Large, but moderately complex process failures
d. Large and complex process failures

Each group will include event sequences that lead to a similar challenge to an operating module's safety related equipment functions and barriers and would need similar mitigating actions/systems to maintain the existing operating facility in a safe state. Each group of PIE's are further subdivided into categories based on frequency of occurrence and severity of impact to the operating SSCs.

8.6 Accident Analysis Types

Provided is a brief overview of the accident analysis methods and accident causation models that will be used in construction accident analyses. The increasing complexity of construction methodology can result in changes in accident causation mechanisms. The construction accident analyses team will consist of personnel suitably qualified and experienced in this field to determine the appropriate types of accident analysis to use.

Sequential

Fault Tree Analysis - or FTA. The FTA constructs a tree of events following one another along a timeline. The assumption is that there is a root cause that is responsible for the initiation of the accident and that the cause-effect relationship is linear and deterministic.

Epidemiological

Epidemiological methods are also modelled around events, but they add a layer of the latent and active conditions that are present or inherent in the system structure or component before the beginning of an accident to the model. This technique looks beyond the proximal cause of the accident and examines the impact of the underlying conditions to the severity of the accident. A more comprehensive understanding of the accident can be obtained.

Systemic

Systemic methods are typified by examining the interfaces between the various subsystems and components of the system that directly affect each other. Rather than treating an event as a series of cause and effects relationships, this method examines the potential that operational interfaces may unknowingly create unsafe conditions that can lead to an event. Simply removing the apparent root cause of an event may not prevent it from recurring.

8.7 Independent Verification of the Construction Hazards Analysis (CHA)

Atomic Alchemy along with its design engineering consortium partner will perform an independent verification of the CHA. The verification team will consist of personnel suitably qualified and experienced in such analysis who did not participate in the development of the original analysis. The verification team will take into account the quality assurance reviews previously performed to determine the extent and scope of its verification. The scope of the verification may be narrower than the entire analysis focusing on the most significant issues. The independent team will focus on a qualitative overall review of the quality and comprehensiveness of the safety analysis along with specific detailed reviews of important aspects of the analysis.

The independent verification report will confirm the following:

a. That the construction safety analysis was performed in accordance with applicable regulations, safety standards and other appropriate guidance.
b. The selected postulated initiating events accurately reflect specific design features and bound any other potential cases.
c. The combination of individual initiating events and the identification of resultant failures was conservatively performed.
d. The computer codes used in DSA have been adequately verified and validated through the Atomic Alchemy QAPD program.
e. The assumptions used in each uncertainty analysis have been selected in an appropriate manner to demonstrate that the acceptance criteria can be met while allowing for sufficient margins to prevent cliff edge effects.
f. Sufficient sensitivity studies were performed in order to ensure that the safety analysis is satisfactorily robust.
g. The operability of facility's safety systems in their respective states was in accordance with their design basis assumptions and consistent with industry standards.
h. Compliance with the relevant acceptance criteria was achieved either by means of automatic systems, or personnel actions were assumed only in cases where contextual boundary conditions for diagnosis, decision and performing the required action were available.
i. Independent verification calculations are congruent both qualitatively and quantitatively with the original analysis calculations and both conclude that the respective acceptance criterion is met.

The independent verification will be documented in a separate report which describe the scope, level of detail, rational for the scope and level of detail, methodology used, computer programs and calculations used, and findings and conclusions. The report will be controlled in accordance with the Atomic Alchemy QAPD program.

9.0 CONSTRUCTION INDUCED ACCIDENTS

Although the following list of postulated initiating events for construction accidents is neither complete nor all-inclusive, it represents a preliminary selection of events that will be considered for this position paper, it should not be relied on exclusively. The Atomic Alchemy construction engineering A/E consortium partner will develop a site specific list on initiating construction events in the HAZID report. Loss of offsite AC power is assumed to occur in the operational modules coincident with all of the construction PIEs.

9.1 Selection of Construction Postulated Initiating Events

Dropping of a Heavy Load (Critical lift[28])

Movement of heavy loads around the construction site are administratively controlled by procedure. The operating module buildings will have above load restricted travel areas identified as part of the crane study that be performed by the A/E construction consortium partner. The crane operating procedures will be developed using ASME B30 "Cranes and Related Equipment" and OSHA critical lift safety standards. Historical data referenced in NUREG-0612 is reviewed in developing the construction PIEs. For the purpose of this position paper, only construction PIEs that occur during Phases 2 and 3 are evaluated. For each load drop scenario an evaluation is made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating construction events resulting from:

a. Structural crane failure due to weather or external event
b. Structural crane failure due to incorrect or excessive loading
c. Structural crane failure due to human error (addressed below)
d. Structural crane failure due to an equipment malfunction (i.e. loss of hoisting or lowering capability coupled with loss of brakes, addressed below)
e. Structural crane failure caused by loss of component power (addressed below)

The consequences of each construction heavy load PIE will consider the local impact response of the existing operating module structures, systems, and components, which may lead to severe damage such as crushing, perforation, and concrete missile type ejections in the vicinity of the impactive load. External missile transients for the operating modules are evaluated in FSAR Chapter 15 for the operational safety related systems and components. Consequences to the operating SSCs in terms of reactions away from the load is typically insignificant. Since the path for movement of heavy administratively controlled, the worst-case DBE construction PIE from a dropped load will be bounded by the facility's DBE transient analysis. However, it is more likely to just result in an event that could be bounded by an anticipated operational occurrence (AOO).

Loss of the Electric Grid/Loss of Sitewide Power

The Atomic Alchemy construction A/E consortium partner will be responsible for developing, inspecting, testing, and installing the necessary on-site construction electrical systems, including lighting (with sufficient UPS) and grounding systems.

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[28] A critical lift definition includes the following:

a. Damage that would result in serious economic consequences
b. Damage that would result in unacceptable delay to schedule or other significant deleterious programmatic impact
c. Undetectable damage that would jeopardize future operations or safety of a facility
d. Significant release of radioactive or other hazardous material to the environment
e. Any lift that requires the use of multiple cranes
f. Any lift that exceeds 80% of the crane's rated capacity within the lift configuration of the crane
g. The item, although non-critical, requires exceptional care in handling because it is being lifted above a critical item

For the purpose of this position paper, only construction PIEs occurring during Phases 2 and 3 are assessed. Loss of power to individual construction machinery and equipment is evaluated separately as part of the overall failure of that specific piece of equipment.

[

]PROP When the location is determined, a more site specific detailed electric power scheme will be developed. It is presumed that construction electric power will be tied into the electric grid and augmented with high powered (200 kW-2500 kW) diesel generators and will possibly require underground routing of some construction power due to extreme weather conditions at the site.

The phased construction plan may also require different configurations for power, in some instances additional MCCs, switch gears, transformers, load bank connections and/or isolation breakers would be necessary. Individual equipment will be tested, along with a system test and arc flash analysis as part of the commissioning of the electrical systems before construction begins. The maintenance of the construction site electrical system will be administratively controlled by the construction group. Loss of Offsite Power (LOOP) transients are evaluated in FSAR Chapter 15 for the operational safety related systems and components.

For each loss of site power PIE an evaluation is made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating construction site power loss events resulting from:

a. Weather or external events
b. Incorrect or excessive loading
c. Malfunctions of electrical equipment, spurious activation/deactivation

A loss of site wide power has the potential to impact multiple pieces of construction machinery simultaneously. The worst-case scenario DBE construction PIE out of these is presumed to impact equipment involving a critical lift. A critical lift PIE has been previously determined to be bounded by the operating facility's DBE transient analysis.

Erroneous Handling of Equipment or Components (due to operator error)

The operation and handling of mechanical/electrical equipment around the construction site are administratively controlled by procedure. The Atomic Alchemy construction A/E engineering consortium partner will be responsible for developing Functional Task Analyses (FNTA) elements of the Atomic Alchemy HFE program for use of construction related activities and equipment.

The results of these analyses establish the number of personnel needed to complete each task, the Human System Interface (HSI) inventory requirements, (including alarms, controls, displays, procedures, and knowledge), and abilities needed to support performance of construction tasks. The FNTA is conducted and implemented in accordance with the applicable guidance provided in NUREG-0711.

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each failure of equipment arising from an erroneous handling of equipment or components PIE, an evaluation is made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating construction erroneous handling of equipment failure events resulting from:

a. Environmental/fatigue conditions of employee
b. Incorrect or incomplete written procedures
c. Inadequate communications
d. Inadequate operator training
e. Inadequate lockout/tagout by employee
f. Inadequate operator qualifications

Atomic Alchemy employees are trained in accordance with the NQA-1 level program "Non-Licensed Plant Staff Training Program" which will be developed to meet the requirements 0f 10 CFR 50.120. Construction employees will be similarly indoctrinated into site procedures and programs and trained to the level corresponding to their occupation. The Human Error Probability (HEP) is already established for the majority of industry construction related tasks. Human Reliability Analyses (HRA) are used to identify potential failure events of new tasks or those that are not performed often. A safety culture will be established at all levels among the construction personnel involved from the early stages of the project with the Atomic Alchemy Safety Conscious Work Environment program. Key best practices such as the use of STAR (Stop, Think, Act, Review) will be implemented to minimize any operator error PIEs.

The worst-case DBE construction PIE caused by an operator error will be presumed to affect a critical lift, (assuming any of the following initiating causes: poor line of sight, lift zone intrusion, improper communication from crane signal person, incorrect hold points or check points, rapidly changing environmental conditions, incorrect lift calculation/analysis). Under this scenario, the construction PIE for an erroneous handling of equipment failure will be bounded by the operating facility's DBE transient analysis.

Malfunction of Construction Equipment or Components

The maintenance of mechanical/electrical equipment around the construction site will be administratively controlled by procedure.

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each malfunction of construction equipment or components PIE, an evaluation will be made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating construction equipment failure events resulting from:

a. Environmental/fatigue conditions
b. Inadequate maintenance
c. Inadequate rework or repairs
d. Spurious activation or deactivation

e. Inadequate lockout/tagout

The Atomic Alchemy A/E construction consortium partner will develop housekeeping requirements in accordance with NQA-1-2017, Part II, Subpart 2.3, "Quality Assurance Requirements for Housekeeping at Nuclear Facilities" to ensure that site machinery and equipment will be properly maintained.

The worst-case DBE construction PIE caused by malfunctioning machinery or components will be presumed to affect either 1) a critical lift, (assuming the following initiating cause: inadequate maintenance or repairs) or 2) handling of toxic or explosive materials (evaluated below). Under either of these scenarios, the construction PIE for an erroneous handling of equipment failure will be bounded by the operating facility's DBE transient analysis.

Failure of Construction Equipment or Components Arising from External Events

The operation and handling of equipment around the construction site are administratively controlled by procedure. Planned construction evolutions and activities are modified or halted based on forecastable inclement weather. Construction equipment (and potentially operating reactors and radioisotope processes) are placed in safe conditions prior to the arrival of any significant inclement weather. Construction equipment (and operational module buildings) are protected by the site's lightning and ground systems. All-weather construction techniques limit the duration that construction would be halted for inclement weather events.

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each failure of equipment arising from an external event PIE, an evaluation will be made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating construction equipment failure events resulting from:

a. Extreme weather (i.e. lightning strikes, severe snowstorms, floods, tornados)
b. Seismic events
c. Naturally occurring fires/smoke
d. Aircraft crash (addressed in another section)
e. Biological phenomena
f. Flooding caused by firefighting equipment

Naturally occurring nearby fires, with severe smoke or nearby flooding can be mitigated in the same way as inclement weather, by modifying or ceasing construction related activities and placing the operating facility's SSCs in a safe shutdown mode.

The Atomic Alchemy Ultimate Heat Sink (UHS) does not rely upon external natural sources of water such as lakes or rivers. Therefore, any related biological accidents arising from temporary construction ponds would have no impact on the operating systems and components' UHS.

In the event of a construction site fire, the operating reactor and radioisotope processes would be placed in a safe shutdown mode. As a result, any flooding conditions caused by external firefighting conditions would not challenge the safety of the facility nor exceed any DBE.

Unforeseeable external events such as seismic events therefore present the only significant construction related PIE arising from the failure of equipment due to an external event. A significant seismic event has the potential to impact multiple pieces of construction equipment and machinery along with simultaneously impacting the SSCs in the modules that are operating.

The geological and seismological information presented in Atomic Alchemy FSAR Chapter 4, Section 5 will be developed from a review of previous reports [

]PROP The Atomic Alchemy facility design will conform to the requirement to withstand the effects of natural phenomena, such as earthquakes, without loss of capability of SSCs to perform their safety functions. Thresholds will be established in procedures for actions required of the plant operators after an earthquake has occurred. Recordings from the seismic monitoring system are evaluated against the SSE design basis for the safety related structures and equipment. All safety related equipment is expected to perform their intended design basis functions following the SSE. Atomic Alchemy provides NQA-1 level administrative controls to SSE systems and components under the Safe Shutdown Equipment List (SSEL) and Seismic Equipment List (SEL) Programs.

The worst-case DBE construction PIE caused an external event (presumed seismic) would affect a critical lift, (assuming that a single failure crane nevertheless topples and/or drops its load). Under this scenario, the construction PIE for an equipment failure caused by an external event (presumed seismic) will be bounded by the operating facility’s DBE transient analysis.

<u>Toxic Chemical Spill / Toxic Chemical Airborne Release</u>

The handling of toxic chemicals around the construction site are administratively controlled by procedures derived from OSHA construction site standards. Construction employees are trained and wear appropriate environmental and personal protection including air monitoring devices as required.

SEC

Among the principal gases for which releases will be considered for the PIE are chlorine, hydrogen sulfide, ammonia, and sulfur dioxide.

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each toxic chemical release construction PIE, an evaluation will be made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree will be developed evaluating potential construction chemical release events resulting from:

a. Storage tank rupture
b. Release caused by explosion (addressed below)
c. Release caused by equipment malfunction or failure (addressed previously)
d. Release caused by operator error (addressed previously)

e. Delivery tank truck release following an accident (non-radionuclide)
f. Heavy gas clouds formed by cold gas – air mixtures
g. Concrete batch process release (electrostatic precipitators, coal pulverizing, kiln burning)
h. Nominal construction evolutions that can produce large quantities of toxic fumes or gases
i. Corrosive atmospheric effects days or weeks later from toxic chemicals generated following a fire
j. Toxic fumes created by an electrical cable fire
k. Aircraft crash (addressed in another section)

The location of the Atomic Alchemy facility will be situated on

[PROP] Therefore, the release of corrosive gases or liquids from industrial plants close to the site or in transit, such as in accidents and spills from trucks or trains, does not constitutes a potential hazard to the Atomic Alchemy facility and are not included in the Facility's DBE.

Atomic Alchemy evaluates toxic gas hazards by analysis, which will be summarized in FSAR Chapter 6, Section 8, subsection "Toxic Gas Hazards". The analysis uses the methodology described in NUREG-0570, "Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release." The Main Control Room (MCR) will be designed with habitability systems which provide the capability to detect and protect main control room personnel from external fire, smoke, toxic chemicals, and airborne radioactivity. Automatic actuation of the individual systems that perform these habitability systems functions will also be provided.

The Atomic Alchemy fire protection plan's recovery steps and fire hazards analysis will address potential latent corrosive atmospheric effects on systems, structures and components following a fire. This would also include evaluating the state of light-water reactor and spent fuel pools following any wash down of firefighting chemicals into the pool.

Accidents involving the transportation of new reactor fuel, SNM stock to or radioisotope products from the Atomic Alchemy facility is bounded by the facility's DBE in FSAR Chapter 15. The impact of such an accident on the construction site would be addressed by the Site Emergency Plan. Elements of the plan will be augmented to suit Phase 2 and Phase 3 construction activities in the UFSAR. This will be further described in another section of this position paper.

The worst-case DBE construction chemical airborne PIE will be presumed to be based on either 1) toxic airborne fumes produced by hot asphalt during hot tar roofing and/or road paving accident or 2) large clouds of toxic substances from an explosion at the concrete batch plant that could affect safety related ventilation systems. Either of these scenario's impact on the operating facility would be bounded by the operating facility DBE transient analysis.

Fires

Fire loads within nuclear facilities are kept to the minimum by the use, as far as practicable, of suitable non-combustible materials. A construction related PIE is not assumed to also lead to a fire that develops further consequences for safety related systems in the operating facility.

Only one fire is postulated to occur at any one time, however, consequential fire spread will be considered part of this single event. In the design of fire protection systems and equipment, some combinations of fire and other postulated initiating events likely to occur independently of a fire will also be evaluated.

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each fire construction PIE, an evaluation is made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating potential construction fire events resulting from:

a. Oil filled transformer fires
b. Weather induced fire (i.e., lightning strikes)
c. Rupture of pipes conveying flammable gas fires
d. Compressed flammable gases storage fires
e. High voltage electric arcing fires
f. Concrete production chemical fires
g. Electrical cable fires
h. Wooden concrete form fires
i. Aircraft crash fuel fire (addressed in another section)
j. Fuel tanker truck crash fires

The Atomic Alchemy fire protection plan will be provided in FSAR Chapter 9, Appendix A, it complies with NFPA 804 and 10 CFR 50.48. A more detailed description is provided in another section of this position paper. The Atomic Alchemy facility will be divided into fire areas and fire zones. These fire areas/zones and their boundaries are analyzed to determine the type, quantity, and distribution of in-situ combustible material and for the principal systems and safety-related components in the fire area. The Atomic Alchemy Fire Hazards Analysis (FHA) includes the following:

a. Confirms the capability to safely shut down the reactor(s), radioisotope and radwaste processes following a fire.
b. Evaluates the consequences of reactor confinement module building fires on radioisotope and radwaste processes and vice versa.
c. Evaluates the consequences of any related fire hazard created by phased construction activities of remaining Reactor modules on the operational Reactor(s) and Radioisotope and Radwaste processes.

The Atomic Alchemy fire protection plan's recovery steps and fire hazards analysis would address potential latent corrosive atmospheric effects on systems, structures and components following a fire. This would also include evaluating the state of light-water pools following any wash down into the light-water pools of firefighting chemicals.

The worst-case DBE construction PIE caused by a fire will be presumed to be either 1) widespread concrete wooden form fire or 2) concrete batch plant fire. Under these circumstances, these construction PIEs for a fire will be bounded by the operating facility's DBE transient analysis.

Explosions

The operation and handling of explosives around the construction site are administratively controlled by procedures found in the Construction Explosives Material Handling and Control Program, an NQA-1 quality program, that will control all explosives within the owner-controlled access construction area and ensure that explosives are handled in accordance with all applicable local, state, and federal requirement (i.e., ATF 555.218 "Table of Distances for Storage of Explosive Materials"). Introduction of explosive materials into the protected and vital areas are administratively controlled by the site security plan.

Malevolent explosions resulting from an adversarial attack are addressed under the "security incident" construction PIE.

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each explosion construction PIE, an evaluation will be made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating potential construction explosion events resulting from:

a. Accidents related to the unintended misuse of construction explosives
b. Oil filled transformer explosions
c. Rupture of pipes conveying flammable gas explosion
d. Compressed flammable gas storage tank explosion
e. Concrete batch plant explosion
f. High voltage electric arcing explosion
g. Boiling liquid expanding vapor explosion (BLEVE)
h. Electrical battery room hydrogen deflagration and/or detonation
i. Potential for fire related secondary explosions occurring within or adjacent to an ongoing fire area
j. Aircraft crash related explosion (addressed in another section)

Chemical Process Safety and Surveillance Program and the Explosive Gas and Radioactive Storage Tank Monitoring Program are Atomic Alchemy Technical Specification level programs to administratively control the potential for explosions within the protected and vital areas.

The Atomic Alchemy construction team will utilize new advanced excavation methods such as precision line blasting and chemical foam expansion for the breaking of rock, these methods greatly reduce the quantities of explosive materials on-site. As stated previously, NQA-1 level programs are in place for the accounting of all explosive materials.

Atomic Alchemy employs a safety related combustion gas monitoring system in the design of the reactor confinement module and radioisotope process module buildings for conservatism. Therefore, secondary explosions due to buildup of combustible gases resulting from fires in adjacent fire zones would be prevented by these administrative controls. The non-safety-related fire protection smoke exhaust systems can also be utilized to purge any combustible gases, and natural convection will saturate and minimize any local accumulation of combustible gases inside the confinement building module.

Features to improve general structural integrity against catastrophic failure or collapse of building structures caused by an explosion will be already incorporated into the design (structures are seismic Cat I) and include redundant emergency exits and the effective placement of the main control room, light-water pools, hot cells, and other safety related mechanical/electrical systems away from any external walls and/or below grade. The operational facility will be further optimized by a robust Emergency Plan and Fire Protection Plan which facilitates firefighting, safe shutdown, evacuations, search and rescues, and facility recovery efforts.

The worst-case construction PIE caused by an explosion is presumed to be caused by any one of several PIEs, 1) outdoor oil filled transformer explosion, 2) compressed flammable gas storage explosion or 3) concrete batch plant explosion. Under any of these scenarios, the construction PIE for an explosion will be bounded by the operating facility's DBE transient analysis.

Loss of Large Area (LOLA)

A Loss of Large Area (due to fires, toxic releases, or explosions) is considered a Beyond Design Basis Event[29] in the Atomic Alchemy FSAR Chapter 19. A construction related PIE is not postulated to escalate to a LOLA event that would then develop even further consequences for the operating safety related systems. A construction initiated LOLA will also be considered a BDBE.

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each loss of large area construction PIE, an evaluation is made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating a hypothetical construction LOLA event resulting from:

a. Previously postulated fire expansion
b. Previously postulated explosion expansion
c. Aircraft crash related fire and/or explosion (addressed in another section)

In addition to potential widespread damages to construction equipment, new equipment storage, testing facilities etc., a LOLA construction event will be hypothesized to have the potential to cause significant damage to operating modules that would include:

a. Contamination of the reactor light-water pools by fire protection systems

[29] While the NRC position on 10 CFR 50.155 in the public register (Federal Register / Vol. 84, No. 154 / Friday, August 9, 2019) stated that BDBE would not be applicable to a non-power reactor facility, that staff determination was made at a time when non-power test reactor facilities were limited to a single reactor. The applicability of an BDBE on a multi-reactor NPUF facility is conservatively evaluated.

b. Spurious actuation of safety related systems with subsequent significant detrimental effects and unavailability of these safety related systems or components when required
c. The presence of corrosive airborne products of combustion. These products may be transported into additional areas remote from the origin of the fire where they can cause subsequent corrosion of SSCs that can create equipment failures many hours or days after the initial fire incident
d. The presence of toxic airborne products of combustion. These products may be transported into additional areas remote from the origin of the fire where they can cause harmful effects on the MCR personnel or emergency response personnel
e. Smoke damage to multiple HVAC systems including the MCR
f. Fire spread to charcoal bed filter systems
g. Water damage to multiple electrical systems
h. Detrimentally affect multiple emergency escape or rescue routes

A design-specific assessment (Loss of Large Area – LOLA, FSAR Chapter 19, Appendix A) of the effects on operating the Atomic Alchemy facility from the beyond design basis event consequences of a loss of large area will be performed using the methodology (in the Non-Security Related Information (NSRI) portions) of NEI 06-12, "B.5.b, Phase 2 & 3 Submittal Guideline" which includes guidance for new plant applications. [

SEC

Because of the inherent significant design differences between larger power reactors and the Atomic Alchemy VIPR designs, loss of large area type accidents that may result in extreme consequences in power reactors such as Ex-Vessel, High Pressure Melt Ejection (HPME), In-Vessel Steam Explosion (IVSE) etc., are not feasible in the Atomic Alchemy VIPR design.

The Atomic Alchemy FSAR LOLA analysis will identify the design features and functional capabilities that demonstrate:

a. Enhanced firefighting capabilities
b. Actions to minimize the release of radioactive materials
c. The reactor core remains cooled
d. Light-water pool integrity is maintained
e. Radwaste storage integrity is maintained
f. The dispersion of radionuclides remains within the limits of 10 CFR 20 Subpart D

Some of the enhanced design features include the design and location of three-hour, 5 psid fire barriers, including walls, floors, fire dampers, doors, equipment access doors, labyrinth type entrances, and 5 psid penetration seals within the reactor confinement module, reactor auxiliary module, radioisotope module buildings for the protection of the reactor light-water pool from the effects of a loss of large area construction event.

Atomic Alchemy will modify the Fire Protection Plan in the UFSAR for each phase of construction to augment the plan along with firefighting capabilities of the fire brigade as necessary. This will also include consideration of the use of movable temporary fire separation walls and other similar separation devices to protect the operating facility from ongoing construction areas.

The worst case construction PIE caused by a LOLA (other than an aircraft impact which is evaluated separately in this paper) is presumed to be either 1) outdoor oil filled transformer explosion that subsequently creates multiple fires and spreads over a large area challenging the operating modules or 2) compressed flammable gas storage explosion that subsequently creates multiple fires and spreads over a large area challenging the operating modules. Under these circumstances, the construction PIE for a LOLA will be bounded by the operating facility's BDBE transient analysis.

Explosions or Fires Caused by Aircraft Impact

An aircraft impact (creating fires, toxic gas releases, or explosions) is considered a Beyond Design Basis Event in the Atomic Alchemy FSAR Chapter 19. A construction related aircraft impact PIE will also be considered a BDBE.

While the NRC position at the time of publishing 10 CFR 50.155 in the public register was that a BDBE would not be applicable to a non-power reactor facility, that determination was made at a time when non-power test reactor facilities were limited to a single reactor. Therefore the possible applicability of an BDBE on a multi-reactor facility is conservatively evaluated (until such time the NRC applies that exclusion to multi-unit non-power reactor facilities).

For the purpose of this position paper only, construction PIEs that occur during Phases 2 and 3 are evaluated. For each AIA construction PIE, an evaluation will be made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating potential construction AIA events resulting from:

a. Military aircraft armed with conventional weapons crash
b. Fuel ladened large commercial aircraft crash

The VIPR reactors are located within a light-water pool inside a reactor confinement module building below grade, these portions of the Atomic Alchemy facility are not susceptible to a direct impact by an aircraft (additionally, elevations or portions of elevations may be screened from aircraft impact if intervening or adjacent structures meet the design requirements of NEI 07-13). The Atomic Alchemy VIPR confinement modules are "nestled" in between the Administration/Service Module, the Reactor Auxiliary Modules, and the Radioisotope Process Modules.

The reactor confinement structure and radioisotope process structure are Seismic Cat-I, built to ACI 349, and AISC-N690 standards. A design-specific assessment (Aircraft Impact Analysis – AIA, FSAR Chapter 19, Appendix B) of the effects on the Atomic Alchemy facility of the BDBE impact of a large commercial aircraft will be performed in accordance with 10 CFR 50.150(a). Because of the inherent significant design differences between larger power reactors and the VIPRs, loss of large area type accidents that result in extreme consequences such as Ex-Vessel, High

Pressure Melt Ejection (HPME), In-Vessel Steam Explosion (IVSE) etc., are not technically feasible in the Atomic Alchemy reactor design.

The Atomic Alchemy FSAR AIA analysis will identify the design features and functional capabilities that demonstrate:

a. Actions to minimize the release of radioactive materials
b. The reactor core remains cooled
c. Light-water pool integrity is maintained
d. Radwaste storage integrity is maintained
e. The dispersion of radionuclides remains within the limits of 10 CFR 20 Subpart D

Some of the enhanced design features include the design and location of three-hour, 5 psid fire barriers, including walls, floors, fire dampers, doors, equipment access door, and 5 psid penetration seals within the reactor confinement module, reactor auxiliary module, radioisotope module buildings. Passive design features include location of the light-water pool and transfer canal pools below grade, the location of the reactor confinement module building partially screened behind the reactor auxiliary and administration/service module buildings, and the ability of the safe shutdown of the reactor to be maintained by convection cooling alone. These features increase the level of protection of the reactors from the effects of an aircraft impact construction event.

Atomic Alchemy will modify the Fire Protection Plan in the UFSAR for each phase of construction to augment the plan and firefighting capabilities of the fire brigade as necessary.

The worst-case construction PIE caused by an AIA is presumed to be either 1) military aircraft carrying conventional weapons causing several initial large explosions with subsequent large area fires or 2) large commercial aircraft that causes an initial explosion with a subsequent large area jet fueled fires. Under these circumstances, the construction PIE for an aircraft impact will be bounded by the operating facility's BDBE transient analysis.

Security Incident

The security around the construction site will be administratively controlled by procedure. For each security construction PIE, an evaluation will be made to determine if the event impacts safe shutdown equipment, spent fuel equipment, or can lead to a criticality. A fault tree is developed evaluating potential security events resulting from: [

]SEC

The above security construction PIEs are bounded by the primary threat event analyzed for the operating Atomic Alchemy Security Plan. The primary threat from a security-initiated incident is a [

SEC

The Atomic Alchemy module buildings are designed for conventional loads (seismic, weather, missile etc.,) and then evaluated for responses to explosive loads per federal anti-terrorist design building [30] guidelines. Features to improve general structural integrity against catastrophic failures or collapse of building structures caused by an explosion will already be incorporated into the design (structures are seismic Cat I) and include redundancy of emergency exits and effective placement of the main control room, light-water pools, hot cells and other safety related mechanical/electrical systems away from any external walls and/or below grade.

The operational facility will be further optimized by a robust Emergency Plan and Security Plan which includes NQA-1 level programs such as Cyber Security Program, Insider Mitigation Program, and the Construction Area Behavioral Observation Program which facilitates safe shutdown, firefighting, evacuations, search and rescues, and recovery efforts along with electronic and physical preventative measures. See a detailed description of the Emergency Plan and Security Plan in another section of this position paper.

The worst-case construction PIE caused by a security threat is postulated to be the same as the primary threat analyzed in the FSAR for the operating facility's DBE. Therefore, the construction PIE security threat will be bounded by the operating facility's DBE transient analysis.

10.0 CONSTRUCTION START-UP AND TESTING INDUCED ACCIDENTS

The commissioning, startup, and testing of new SSCs that interface or interact with existing operating systems and components presents a different set of postulated construction related induced accidents, which will also be evaluated by the construction A/E consortium partner in the HAZID report.

Prior to commencing startup testing, the Atomic Alchemy's QAPD, Part I, Section 11.3, Operational Readiness Assessment Program (See also FSAR Chapter 14) evaluates the status of the facility's completion of system turnovers, punch lists, inspections, etc. to establish the basis for supporting the conclusion that 10CFR50.57(a)(1), (2), (3) has been satisfied and there are no outstanding issues for which Atomic Alchemy has not developed adequate corrective actions, in preparation for the NRC's Operational Readiness Assessment Team (ORAT) Inspections.

The scope of the operational readiness assessment focuses on four major areas: system readiness, functional area readiness, programmatic readiness, and equipment readiness. The scope will be

[30] FEMA 427 "Primer For Design Of Commercial Buildings To Mitigate Terrorist Attacks", and FEMA 426 "Reference Manual To Mitigate Potential Terrorist Attacks Against Buildings".

expanded to include any emergent issues. A multi-discipline Engineering Review Board (ERB) will be assembled to perform a technical review of any potential operational readiness issues.

The Atomic Alchemy Construction A/E consortium partner will be responsible for developing the Pre-Operational Testing Specifications and Procedures as well as the Start-Up Testing Specifications and Procedures. These specifications and procedures are developed in part using the guidance on managing the transition from construction to operation for nuclear facilities found in NQA-1-2017, Part VI, Subpart 4.2.5, "Guidance on the Transition from Construction to Operation for Nuclear Facilities".

10.1 Startup, Testing and Commissioning PIEs for Safety Related Shared Systems and Components

Electromagnetic Interferences

The safety related equipment sensitive to electromagnetic radiation is identified during the early electrical and I&C design phases. The systems and components will be qualified by the Atomic Alchemy Electrical Equipment Qualification Program and the TRM quality level Electromagnetic Compatibility and Radio Frequency Interference (EMC/RFI) Program to show that they can withstand the electromagnetic environment that they will be exposed to.

During the development of the construction plan the A/E construction consortium partner is responsible for initially verifying that all construction related potential EMC/RFI components (high voltage switch gears, portable telephones, portable electronic devices, computers etc.) do not pose a credible threat to the operating sensitive equipment. This initial development will help in writing the EMC specifications for custom-engineered construction equipment and components.

During construction phases, the construction team will conduct periodic EM surveys. The potential for EM phenomena is tested on a range from DC to 40GHz, including continuous and/or transient radiated and conducted phenomena. Power quality surveys (dips, dropouts, harmonics, interharmonics, etc.) are also included in these surveys.

The VIPR Shared Safety-Related SSC

As previously described in the Multi Unit Key Regulatory Issues section of this position paper, with respect to General Design Criterion 5, the only shared safety related system between VIPRs would be the Mo-99 light-water transfer canal pool.

This pre-operational and startup testing situation would only arise during Phase 2 construction (as the two VIPR reactors constructed in Phase 3 would both be undergoing similar startup testing and turnover simultaneously). The volume of water stored in the TTW system light-water transfer canal pool is sufficiently sized for decay heat removal for two VIPR light-water reactor pools on a loss of coolant accident [31]. Therefore, even during hot functional testing of the Safety Class A, Quality Class A, and Seismic Cat-I components of the DHR system for the newly constructed VIPR the operating VIPR makeup water source would not be impaired.

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[31] A Large Break or Small Break LOCA in which the reactor core is uncovered is not a credible RCS design basis transient in the FSAR Chapter 15 accident analysis. The effects of such a hypothetical transient have however also been analyzed for BDBE.

The worst-case construction startup testing PIE related to TTW and DHR systems and components would be a stuck open flow check valve that would drain more than half of the volume of the transfer canal pool. This would result in the operational VIPR entering into T/S 3.5.1 (operability of the DHR system) Limiting Conditions of Operation (LCO). This condition would be bounded by the operating facility's DBE transient analysis. As hot functional testing procedures are developed in detail, some additional administrative controls (i.e., adding a temporary partition to the TTW light-water transfer canal pool to limit the available volume for testing) may be determined to be placed on the operating radioisotope process for specific construction evolutions.

The Radioisotope Process Shared Safety-Related SSCs

Electrical and I&C Systems

As previously described in the Multi Unit Key Regulatory Issues section of this position paper with respect to General Design Criterion 5, Atomic Alchemy does not apply this GDC criterion [32] to its principal design criterion for the radioisotope production process safety related SSC's. (See Tables 16.01 and 16.02 for a listing of preliminary design radioisotope shared safety and reactor and radioisotope shared non-safety-related systems respectively)

For Phase 2 construction there will not be any impact on the operating Atlantia radioisotope process and its support target fabrication and radwaste module buildings, as only the VIPR module Pegasus is being constructed and turned over to operations.

Only during Phase 3 construction (the Pacifica radioisotope process module and its supporting target fabrication and radwaste module buildings) does this potential testing situation arise for shared safety related systems between the two main radioisotope process module buildings (Atlantia and Pacifica).

Offsite AC power has no safety-related function due to the passive design of the Atomic Alchemy Facility. The on-site power system is comprised of the main AC power system and the DC power system. The main AC power system is a non-Class 1E system. The DC power system consists of Class 1E and non-Class 1E DC power systems. Each DC system consists of ungrounded batteries, DC distribution equipment, and a UPS. The Class 1E DC and UPS system are the only safety-related power sources required to monitor and actuate any safety-related passive systems in radioisotope related processes.

The Class 1E DC and UPS systems that are shared between the radioisotope process modules Atlantia and Pacifica are designed to accommodate component failures (such as the loss of a battery charger, a battery, or an inverter) without the loss of power to either the DC bus or the AC instrumentation and control power bus. The Class 1E DC power systems include a spare Class 1E battery bank with a spare battery, battery charger, and permanently installed cable connections that allow the spare bank to be connected to the affected bus by operator actions.

[32] There are no Title 10 regulatory requirements nor baseline design criterion for restricting the sharing of safety related systems in non-reactor nuclear facilities.

The shared radioisotope Class 1E and non-Class 1E UPS systems will be located within controlled environments. The UPS equipment is rated for continuous operation at an ambient temperature of 104°F. In addition, the temperature-sensitive components such as capacitors, transformers, and semiconductors, used in the UPS equipment are designed to continuously withstand higher temperatures of 158° F. All Class 1E electrical components are safety related and environmentally qualified in accordance with the Atomic Alchemy EEQ program.

Partitioning of shared systems will be accomplished by the design features and start up and testing administrative controls and will not require lengthy restrictions to be placed on any of the operating radioisotope module systems or components' configurations. These design features include multiple trains, different algorithms, qualified gateway isolation devices and breakers that are already provided by design to isolate these systems and components for normal/abnormal operations, T/S surveillances and maintenance.

Software diversity between I&C safety related systems and components for the radioisotope processes will be achieved through the use of various algorithms, logic, program architecture, executable operating system, and executable software/logic. The I&C safety related systems will have electrical Surge Withstand Capability (SWC) and can withstand the electromagnetic interference (EMI), radio frequency (RFI), and electrostatic discharge (ESD) conditions that can be created while new systems and components are being modified.

Signal processing cabinets are provided with the capability for channel testing without actuating the controlled components. The safety related I&C systems provides a minimum inventory of displays, visual alerts, and fixed position controls, along with providing for the transfer of control capability from one display station in the MCR to another in the MCR as well as transferring control to the Remote Shutdown Workstation (RSW) using multiple transfer switches. The I&C safety related systems will automatically remove blocks of any engineered safety features actuation when the facility approaches conditions for which the associated function is designed to provide protection.

The worst-case radioisotope process construction startup and testing PIE related to electrical, or I&C systems and components of the radioisotope process systems would result in an AOO or T/S LCO and be bounded by the operating facility's DBE transient analysis.

<u>Mechanical HVAC, Filtration, Off-Gas Systems</u>

Atomic Alchemy's radioisotope processing related module buildings do not require a dose mitigating ESF type of systems. The Atlantia and Pacifica modules share HVAC, filtration, and off-gas related systems. Some of the systems may be seismic Cat-II due to their location respective to other safety related components. The purpose of the filtration systems are to control normal operating releases and assist in maintaining a negative pressure with respect to the environment and adjacent module buildings. They are not necessary for accident mitigation or isolation.

Partitioning of shared systems will be accomplished by the design features and startup and testing administrative controls and will not require lengthy restrictions to be placed on any of the operating radioisotope module HVAC, Filtration, or off-gas systems or components' configurations. These design features include multiple trains, fans, valves, dampers, spectacle flanges, and breakers that are already provided by design to isolate these systems and components for normal/abnormal operations, T/S surveillances, and maintenance.

The worst-case construction startup and testing PIE related to HVAC, air filtration or an off-gas system and component would be a Double Ended Break (DEB) in piping, tubing, or ductwork and result either in an AOO or a T/S LCO that will be bounded by the operating facility's DBE transient analysis.

Solid and Liquid Systems, Gaseous Systems

Atomic Alchemy will develop a radioactive waste control program in compliance with 10 CFR 61.55, 10 CFR 61.56, and 10 CFR 71. This was identified as regulatory commitment AA0-RC-0013. Atomic Alchemy QAPD Section 1.1.2, organization "Radiation Protection and Waste Services Group" carries out the functions required for managing radioactive waste and disposal. QAPD Criterion XIII, Subsection 13.7.2 will describe the quality controls placed on processing, packaging, and disposal of radioactive waste. These functions are administratively controlled by the Radioactive Waste Program. Atomic Alchemy employs specific methods and procedures to ensure that all liquid and wet wastes in storage will be stabilized in accordance with the Radwaste Program before processing for offsite shipment. The Atomic Alchemy on-site waste storage facilities provide sufficient storage capacity to allow time for shorter lived radionuclides to decay before packaging and shipping.

Atomic Alchemy uses NQA-1 level programs and administrative controls as the means for controlling and limiting radioactive effluents and radiation exposures from the types and quantities of radioactive materials and by-products expected to be produced in the operation of the radioisotope processes. See Offsite Dose Calculation Manual (ODCM) section 5.6.1 "Radioactive Process Effluent Control Program" and 5.6.1.1 "Radiological Environmental Monitoring Program (REMP)". The Atomic Alchemy REMP monitors radiological contaminants from both air and liquid point sources, as well as collects and analyzes environmental samples from numerous locations throughout the site and the surrounding area.

Partitioning of shared systems will be accomplished by the design features and startup and testing administrative controls and will not require lengthy restrictions to be placed on any of the operating radioisotope module radwaste systems or components' configurations. These design features include multiple trains, valves, dampers, pumps, fans, spectacle flanges, and breakers that are already provided by design to isolate these systems and components for normal/abnormal operations, T/S surveillances, and maintenance.

The worst-case construction startup and testing PIE related to solid, liquid, or gaseous safety related systems and components would be a DEB in a pipe or tubing that would result in an AOO or possible T/S LCO and be bounded by the operating facility's DBE transient analysis.

10.2 Startup, Testing and Commissioning PIEs for Non-Safety-Related Shared Systems and Components

Although non-safety-related, the shared systems are designed for operational reliability and availability to minimize restrictions on all NPUF operating configurations during normal modes of operation. The non-safety-related shared systems include design features such as redundancy, spare capacity, isolation, and consideration of system interfaces. These features minimize the effects of a VIPR or radioisotope process out-of-service and testing configurations in order to allow continued full-power operation of the other SSCs. Any potential construction related transient to a non-safety-related shared system or component is bounded by the design basis AOOs. See Table 16.02 for a preliminary listing of potential non-safety-related systems for both the VIPR and radioisotope process modules.

The worst-case construction startup and testing PIE related to non-safety-related systems and components would result in an AOO which would be bounded by the operating facility's DBE transient analysis.

11.0 CONSTRUCTION EMERGENCY PLAN

An emergency response organization will be established by Atomic Alchemy Inc. with specific duties and responsibilities defined and points of contact between on-site and off-site supporting agencies are designated. Augmentation of the on-shift organization is required at "Alert" and higher levels and may occur at a Notification of Unusual Event (NOUE) and include activation of both station and corporate emergency response personnel, as appropriate. Provisions for prompt notification of State, Local and Federal agencies are established and include information which may be required for off-site agency response.

Methods and procedures will provide corrective and protective actions, including evaluation of the operability of the unaffected unit(s). The uses of protective equipment, protective action guides, and exposure limits are also pre-specified. The facilities available for assessment and management of the emergency consists of on-site and off-site response facilities, communication systems, and portable or fixed equipment and systems for detection and measurement of those parameters causing or resulting from the emergency. Medical services will also be available.

A recovery and re-entry plan will describe the management, technical, and administrative organization necessary to execute timely and effective recovery of the facility based on assessments of NPR and/or radioisotope process SSC conditions and desired end states.

The Emergency Plan will be the top-level policy document that establishes the manner in which Atomic Alchemy will respond to any abnormal site events.

11.1 Atomic Alchemy Emergency Plan Overview

NUREG-0849, "Standard Review Plan for the Review and Evaluation of Emergency Plans for Research and Test Reactors" and Regulatory Guide 2.6, "Emergency Planning for Research and Test Reactors" only apply to NPUF facilities licensed under 10 CFR 50.21(c), the Atomic Alchemy NPUF facility will be licensed under 10 CFR 50.22, as such the Atomic Alchemy Emergency Plan will follow the requirements of 10 CFR 50.47[33], and Part 50, Appendix E, which is referenced in NUREG-1537 Part 1, Appendix A.

Title 10, Part 50, Appendix E Section IV.F.2.a.(iii) addresses exercise requirements of Sections IV.F.2.b and IV.F.2.c to be conducted either in full or partially for additional reactors being constructed under Part 52, there is no corresponding requirement for exercise requirements for additional reactors that are licensed under Part 50.

The Atomic Alchemy NPUF construction license and operating license applications are submitted under Title 10, Part 50. For the most part, 10 CFR, Part 52 regulations are not applicable to the Atomic Alchemy NPUF construction and operating license submissions. Atomic Alchemy recognizes that the Title 10, Part 50, Appendix E regulations have not quite kept up with specific advancements in reactor design configurations and the enhancements defined in the newer SMR, ALWR regulations of Part 52. These potential construction issues nevertheless can exist among the new non-power reactor designs. Atomic Alchemy will conservatively address these.

The “General Emergency” class of accident is not a credible transient in the Atomic Alchemy FSAR Chapter 15 transient analysis. The BDBE for the Atomic Alchemy facility does not have a significant radiological impact at substantial distances from the facility. Therefore, this class will not be included in the Atomic Alchemy Emergency Plan.

The Atomic Alchemy Emergency Plan will be based upon NRC and Federal Emergency Management Agency (FEMA) guidance as contained in NUREG-0654/FEMA-REP-1, Revision 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants", and EPA guidance as contained in EPA 400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" October 1991, and Regulatory Guide 1.101. Radiological emergency planning for the Atomic Alchemy Facility will be coordinated with state and local emergency response agencies.

11.2 Atomic Alchemy Construction Emergency Planning

The Atomic Alchemy facility’s Emergency Plan will be augmented for Phase 2 and Phase 3 construction by the Construction Emergency Plan program. This TRM level program will include periodic construction management level reviews to determine any necessary required revisions or modification of the existing emergency plan in the UFSAR for additional staffing and/or training as construction evolutions progress, as well as reportability to the NRC for any temporary changes that might reduce the effectiveness of the plan. The program will be responsible for maintaining accurate up to date evacuation plans and site maps that will be amended on a timely basis to accurately represent the current emergency plan. Construction engineering will maintain access to the latest revisions of Abnormal Operation Manuals and Procedures (AOP), Function Restoration Procedures (FRP), Severe Accident Management Guidelines (SAG) and FLEX Support Guidelines (FSG) which will contain specific

[33] Atomic Alchemy may request exemptions from some of the emergency planning requirements (i.e. size of the EPZ) found in 10 CFR 50.47 in accordance with Part 50 Appendix E Section I.3.

information for construction related activities and personnel. The on-site construction engineering offices will be properly staffed with EP coordinators.

The Atomic Alchemy reactor main control room (MCR) will be kept up to date on all planned construction activities, direct lines of communications in the MCR will also be maintained during all significant construction evolutions taking place on-site. Administrative controls will be placed in the AOPs, FRPs, SAMGs, and FSGs maintained in the MCR to be inclusive of construction site personnel and equipment. Atomic Alchemy may augment the staffing of the MCR to support significant or complex construction activities.

12.0 CONSTRUCTION FIRE PROTECTION PLAN

The Atomic Alchemy Fire Protection Plan will evaluate the potential for occurrence of fires within the facility and will document the capabilities of the fire protection system and the capability to safely shut down the facility. The Fire Hazards Analysis (FHA) will be an integral part of the process of selecting fire prevention, detection, and suppression methods, and provides a design basis for the fire protection system. Firefighting systems are designed such that their rupture or inadvertent operation will not prevent any safety-related systems from performing their design functions.

The Atomic Alchemy facility will be divided into fire areas and fire zones to isolate potential fires and minimize the risk of the spread of fire and the resultant consequential damage from corrosive gases, fire suppression agents, smoke, and radioactive contamination. These zones and areas will be described in the Fire Protection Plan. These fire areas/zones and their boundaries will be illustrated in FSAR Figures 9A-01 through 9A-09. The analysis for each fire area will briefly describe the fire area and associated fire zones and identifies the principal systems and safety-related components in the fire area. Safe Shutdown requirements will be addressed for each area/zone. Fire detection and suppression features will be listed, and the means of smoke control will be discussed. The term "smoke" will be used throughout the Fire Protection Plan to imply "smoke and other products of combustion, including toxic gases". Firefighting personnel access routes and life safety escape routes are also provided for each fire area. Fire exit routes will be clearly marked in the facility.

12.1 <u>Atomic Alchemy Fire Protection Plan Overview</u>

The Atomic Alchemy NUPF facility will be constructed of noncombustible materials to the extent practicable. The selection of construction materials and the control of combustible materials are in accordance NFPA 804. The facility’s module buildings will use noncombustible structural materials, primarily reinforced concrete, gypsum, masonry block, structural steel, steel siding, and concrete/steel composite material. Fireproofing of these steel structures will not be required, but the effects of heat generated by a fire will be considered in the design. Localized structural steel fireproofing will be provided as required, based on a realistic analysis of the time-to-temperature fire and heat effects on some structural members. Fire barriers will be provided in accordance with Regulatory Guide 1.189. Three-hour fire barriers are non-combustible and surround fire areas containing safety-related components. The resistance of fire barriers in non- safety-related areas of the plant may be less than 3 hours, where justified by the FHA. Outdoor fire water piping and water suppression systems located in unheated areas of the facility will be protected from freezing.

The Reactor MCR will be considered one fire area. It will be supported by safety related HVAC ventilation and filtration systems and 1E DC and UPS power. The fire detection system provides audible and visual alarms and system trouble annunciation in the reactor main control room and the main security office.

Electrical and fiber optic cables and the methods of electrical and I&C raceway construction are selected in accordance with Regulatory Guide 1.189. Metal cable trays are used. Rigid metal conduit or metal raceways are used for cable runs not embedded in concrete or buried underground. Each fire detection, indicating, and alarm unit will be provided with reliable non-safety-related AC electrical power and non-Class 1E DC UPS system.

The FHA will describe how materials that collect or contain radioactivity, such as spent ion exchange resins and filters, are protected, and stored. Similarly, the FHA will determine the scope of the fire detection and alarm systems.

Fire Protection systems serving areas containing systems, structures and components required for safe shutdown following the Safe Shutdown Earthquake (SSE) will be designed and supported so that they can withstand the effects of the SSE and remain functional. The FSAR will provide a list of the system capabilities that are expected to be available following a fire to bring the reactor(s) and radioisotope processes to a cold shutdown mode. If a less likely, more severe fire occurs, these systems are expected to be recovered after reasonable actions are taken to utilize temporary connections or to perform repairs.

The Fire Protection system will be tested as part of the ITP which will be described in FSAR Chapter 14.

Preparation and review of the Atomic Alchemy FHA and the design and selection of fire protection equipment will be performed by qualified, experienced fire protection and nuclear safety systems engineers. The qualification requirements for the individuals responsible for development of the FHA, the Fire Protection Program, training of firefighting personnel, as well as associated fire protection related procedures, will be described in FSAR Chapter 9, Appendix A. See FSAR Chapter 1, Appendix A, Atomic Alchemy compliance with Regulatory Guides 1.78, 1.101, 1.120, 1.189, and Regulatory Guide 1.205. The Atomic Alchemy Fire Protection Plan will also satisfy the intent of 10 CFR 70.64(a)(3).

12.2 Atomic Alchemy Construction Fire Protection Planning

Each phase of the Atomic Alchemy construction area will be considered its own fire area that will be subdivided into smaller fire zones. Similar to the Emergency Plan, the FHA will also include an analysis for the 3 phases of construction and develop an adequate fire protection plan to be incorporated in the Facility's UFSAR Fire Protection Plan[34]. A safe shutdown evaluation confirming the capability to safely shut down the reactor(s) and radioisotope processes and to maintain them in a safe shutdown condition following a construction related fire will be part of the FHA. Fire detection alarms from the construction area will annunciate in the reactor MCR and site security main office. A site wide fire protection water loop will also envelope the construction area and will be provided in accordance with

[34] Upon completion of each phase of construction the FHA and other FSAR sections related to fire protection during construction will be modified, and some sections will be designated as "historical" in the UFSAR.

Regulatory Guide 1.189 and NFPA 24. Hydrants are provided on the construction area main in accordance with NFPA 24. They will provide hose stream protection for every part of both the operating NPUF modules and the entire construction area. The NUPF fire protection water supply system may be augmented with additional local or mobile booster fire pumps and/or additional local area water storage tanks during various phases of construction. The fire protection brigade may also be augmented by additional personnel during construction. Manual fire suppression capability will be provided in construction areas.

Atomic Alchemy will perform a Design & Licensing Baseline Verification (DLBV) assessment before low power testing commences on each new reactor. As part of this programmatic review, elements of the previous construction fire protection systems will be analyzed to determine its re-use, relocation, removal, abandonment in place, or isolation as appropriate before beginning the next construction phase. Likewise, the FHA and Fire Protection Plan will be modified in the UFSAR prior to commencement of the next construction phase.

13.0 SITE SECURITY PLAN

The Atomic Alchemy Security Plan is presently being developed, an assessment of security requirements will be conducted in accordance with the guidance in NUREG/CR-7145 and the NEI White Paper: "Proposed Physical Security Requirements for Advanced Reactor Technologies." The Atomic Alchemy Security Plan will be submitted as FSAR Chapter 13, Appendix C.

13.1 Atomic Alchemy Site Security Plan Overview

The plan will follow the guidance of NEI 03-01, 03-09, and NEI 03-12. The Security Plan meets [

SEC

The Plan is categorized as Security Safeguards Information and is withheld from public disclosure pursuant to 10 CFR 73.21, 10 CFR 73.22 and 10 CFR 2.390. Specific elements of the security programs will be assessed by the NRC during the pre-construction inspection phase. [

]SEC Atomic Alchemy will implement the requirements of their Security Plan before entry into Phase 1 construction.

The Atomic Alchemy Security Plan will consist of the following programs within the plan: [

[35] Atomic Alchemy will request alternatives to some security elements under 10 CFR 73.55(r) and/or exemptions under 10 CFR 73.5.

]SEC

Atomic Alchemy provides administrative control of Special Nuclear Material (SNM) with the Special Nuclear Material Accounting and Control Program, a QAPD level program that meets the requirements of 10 CFR 74 Subpart B and C.

The Atomic Alchemy physical security programs will feature the following elements[36]: [

SEC

13.2 Atomic Alchemy Construction Site Security Planning[37]

Similar to the NPUF operating facility's security plan, the Construction Security Plan will also include provisions for all 3 phases of construction and will be incorporated as a subpart to the Facility's UFSAR Security Plan[38]. The Atomic Alchemy construction security will include a FFD and Access Construction Personnel Program that meets the requirements of 10 CFR 26.4(e). The Atomic Alchemy construction security plan will only apply to the owner-controlled designated construction area. Assembly or modular fabrication that occurs outside the owner area are not controlled by the Atomic Alchemy security plan.

Additional construction security program elements will include: [

[36] Because the Atomic Alchemy facility will be located on [ ]PROP some of these security elements will be located at the boundary of [ ]PROP owner controlled area.
[37] In anticipation of regulations 10 CFR 73.52 and 10 CFR 50.34(j) being published Atomic Alchemy will prepare a separate construction security plan as part of the Part 50 operating license application.
[38] Upon completion of each phase of construction the Construction Security Plan and other FSAR sections related to security during construction will be modified, and some sections will be designated as "historical" in the UFSAR.

]SEC

Any other subsequent phased construction activities including those involving safety-related SSC's that will take place within the boundaries of the operating NPUF facility (which is subject to the requirements of 10 CFR 73.55) will be considered to have met the requirements of the construction security plan.

14.0 ADMINISTRATIVE CONTROLS AND MANAGERIAL OVERSIGHT

This section will describe the management oversight and administrative controls in place for Phase 2 and Phase 3 construction, pre-operational, operational readiness, and startup testing.

The Atomic Alchemy QAPD is based on NQA-1-2017, the elements of these quality assurance standards far exceed the quality standards established in ANSI/ANS-15.8-1995, Regulatory Guide 2.5, and as a minimum required under NUREG-1537 Part 2, SRP Section 12.9 for NPUF facilities.

The Atomic Alchemy QAPD Part I, Section 2.1.5, "Multi-Unit Facility Provisions" and Part I, Criterion XI, Section 11.7 "Start-Up Test Program" and the "Operational Readiness Assessment Program" will provide the necessary controls and oversight to demonstrate, insofar as practicable, that the overall operating facility is capable of withstanding the design transients and accidents associated with Phase 2 and Phase 3 construction and testing.

Construction startup and testing programs and related testing procedures for Phase 2 and Phase 3 are developed by the A/E construction consortium partner, and the elements of these are based on NQA-1-2017, Part 1 and Part 2. Multiple sources of operating experience will be reviewed to develop the Initial Test Program for Phase 2 and Phase 3. These included INPO Reports, INPO Guidelines, INPO

Significant Event Reports, INPO Significant Operating Experience Reports, Atomic Alchemy Corrective Actions Program (CAP) reports related to its Phase 1 pre-service and startup testing and NRC Regulatory Guide 1.68.

Other special tests, and First Of A Kind (FOAK) tests which will establish the unique phenomenological performance parameters of the Atomic Alchemy VIPR design features that will not change from reactor to reactor, are performed only for the first two[39] VIPRs. The following is a preliminary listing of the system or component special tests required on the first two VIPRs.

a. RXS system CVAP[40] internal vibration tests
b. RXS rod cluster control tests
c. RCS system core plenum flow circulation tests
d. RCS system check valve flow tests
e. LWP system fluid recirculation convection plenum flow tests
f. LWP system fluid check valve flow tests
g. NSS system recirculation flow test
h. DHR system check valve flow tests
i. RCV, RAV systems natural air circulation and convection heat removal tests
j. RCV, RAV systems isolation damper and air leakage rate tests
k. MHR system remote target capsule handling tests
l. PCS system submerged target canal remote handling tests
m. Use of facility abnormal and emergency procedures

Just as developed for Phase 1, the consortium construction management team for Phase 2 and Phase 3 will consist of an organizational group of authorized representative personnel from the consortium A/E design engineering partner, and the consortium A/E construction partner, the Atomic Alchemy Plant Nuclear Safety Review Committee (PNSRC), the Atomic Alchemy Configuration Control Board Organization (CCBO), and added for Phase2 and Phase 3, the Atomic Alchemy operating facility's maintenance, operations, licensing, and engineering representatives, similar to the Phase 1 team, the Phase 2 and Phase 3 construction teams will further be divided into groups such as the construction quality assurance group, corrective actions group, pre-operational test group, startup test group, work control group, the Atomic Alchemy field engineering group.

An overall construction organization chart will be submitted to the NRC as required, along with a schedule for the major segments of the ITP for each construction phase. Preliminarily, at least 9 months will be allotted for conducting pre-operational testing, and 3 months for startup testing, fuel loading, low power, and power ascension testing.

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[39] A similar listing of radioisotope process systems and components test requirements will be provided in the FSAR that will be performed only for the first radioisotope process modules during Phase 1 construction. This information will be designated as "historical" in the UFSAR.

[40] Comprehensive Vibration Assessment Program (CVAP) is an Atomic Alchemy QAPD level program meeting Regulatory Guide 1.20.

14.1 Administrative Controls

A pre-service test program, which identifies the required functional testing for both the reactor (Phases 2 and 3) and radioisotope processes (Phase 3), will be submitted to the NRC prior to performing the tests and following the start of Phase 2 and Phase 3 construction respectively. These pre-service tests will be described in UFSAR[41] Chapter 14, Section 4 (Reactor pre-operational testing) and/or Section 5 (Radioisotope Process Production Pre-Operational Testing). Each Phase 2 and Phase 3 start-up test described within the UFSAR sections will contain at a minimum a description of the "Objective", "Prerequisites", "Test Methodology" and "Performance Criteria".

A new ITP startup manual prepared by the A/E construction consortium partner, governs the pre-operational and initial startup testing for Phase 2 and then Phase 3. The format of individual test procedures will again be developed to provide consistency with the guidance contained in Regulatory Guide 1.68. Acceptable qualifications of test engineers will follow the guidance provided in Regulatory Guide 1.28. The overall elements of the program will conform to guidance in Regulatory Guide 1.206 Rev 0, Section C.1.14[42].

The ITP will provide for the participation of the principal design departments in creating test objectives, test acceptance criteria, and related performance requirements during the development of detailed test procedures. Each test procedure will include acceptance criteria that account for the same uncertainties used in SAR transient analyses. A review of the approved test procedure to ensure latest drawing revisions, CLB adherence, or any new operating experience etc. will be required before commencement of any test by the lead testing engineer. A formal documented process will be established for the turnover of testing responsibilities during shift changes.

During preoperational testing, it may be necessary to return control authority of a system or component to the construction team to repair or modify an SSC. Administrative controls will be provided in the ITP for turnover, tracking and releasing SSCs as well as identification of required testing to restore the system to operability/functionality/availability status, and to identify tests to be re-performed based on the effect of the repairs performed.

Personnel from the operating module's reactor and radioisotope operations' groups will have the overall responsibility for managing the administrative control for tag-outs sequences for each shared system during testing evolutions. Temporary alterations to operating shared systems (lock out/tag out of a train) or entering into a TRM Technical Requirements for Operation (TRO) or using the Operator Work Arounds (OWA) (implemented under the Atomic Alchemy QAPD level "Operator Work Around Program") may be required to conduct specific steps in pre-operational or startup tests. Any temporary alterations to an operating shared system will be further vetted by the construction team and thoroughly described (and approved) prior to being included in the test procedures. Restoration steps and retesting steps to confirm satisfactory restoration to the original configuration will also be included

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[41] Before beginning the next construction phase the Initial Test and Start plan SAR sections will be modified, and some sections will be designated as "historical" in the UFSAR.

[42] Regulatory Guide 1.206 which was revised in 2018, removed section C.1.14, the elements of the latest revision 1, focus more on a Part 52 COL, ESP and DC submittals, Atomic Alchemy will therefore use the elements from R.G. 1.206, Revision 0, which were more suited for a Part 50 license application.

in the testing procedures. For certain critical construction evolutions additional control room personnel may be assigned to the MCR.

Also incorporated into the Phase 2 and Phase 3 ITP startup tests will be requirements for control room operator participation. During Phase 2 and Phase 3 ITP some additional testing of the revised Atomic Alchemy emergency, abnormal and some normal operating procedures, along with some alarm response procedures and surveillance procedures will be performed.

Startup test reports are prepared in accordance with the guidance in Regulatory Guide 1.68. Pre-operational and startup test results are reviewed and approved by the CCBO of Atomic Alchemy. Each completed test package is reviewed by technically qualified personnel to confirm satisfactory demonstration of plant, system, or component performance as well as compliance with design and license criteria. Review and approval of test results are kept current such that succeeding tests are not dependent on systems or components that have not been adequately tested. Failed tests are identified to the affected and responsible design organizations and entered into the Atomic Alchemy corrective action program. The ITP will establish Commissioning Control Points (CCP) for both the reactor and radioisotope processes.

The Phase 2 and Phase 3 reactor startup test program begins with initial fuel loading after the pre-operational testing has been successfully completed. Like Phase 1, startup reactor testing will be grouped into six broad categories:

a. Tests related to the Technical Specifications
b. Tests related to safety related systems and components
c. Tests related to initial fuel loading
d. Tests performed after initial fuel loading but prior to initial criticality
e. Tests related to initial criticality and those performed at low power (less than 5 percent)
f. Tests performed at power *levels greater than 5 percent*

The Phase 3 radioisotope process SSC start up test programs will be similarly grouped into four broad categories.

a. Tests related to the Technical Specifications
b. Test related to safety related systems and components
c. Tests related to SNM processing and handling
d. Tests related to radwaste processing and handling

Initial fuel loading and subsequent initial criticality and power ascension to full licensed power are performed during the startup test program. Initial pre-requisite conditions for fuel loading will be established in the ITP. Prior to the initiation of these operations, the systems, and conditions necessary to bring the modules into compliance with the Atomic Alchemy Technical Specifications will be operable and all license conditions satisfied.

Atomic Alchemy will also make a commitment (at the time of submission of the testing plan to the NRC) to completing all VIPR safety related ITP Phase 2 (and Phase 3) startup testing prior to ascending above 25% power of any newly construction VIPR modules.

Atomic Alchemy may also commit[43] to preparing and submitting separate "Functional Area and Baseline Inspection Readiness Reports" following completion of both Phase 2 and Phase 3 pre-operational testing as applicable to the reactor and radioisotope process SSC's. These reports will form the basis for supporting the conclusion that the Phase 2 (and Phase 3) elements of 10 CFR 50.57(a)(1), 10 CFR 50.57(a)(2), and 10 CFR 50.57(a)(3)(ii) have been satisfied and there are no outstanding issues for which Atomic Alchemy has not developed adequate corrective actions for.

14.2 Engineering and Construction Management Oversight

Project construction issues and delays often arise when an owner/licensee submits a preliminary design to obtain a nuclear facility construction license from the regulatory authority that it has not sufficiently completed designing. While the scope of design may meet the regulatory authority's threshold criteria for an application submittal, the design nevertheless may have some significant design or construction concerns remaining that will need to be addressed. There is a strong benefit in finishing design before start of construction and integrating procurement, construction, and commissioning requirements with upfront design.

An early collaborative partnership approach allows the owner/licensee's and A/E consortium design and construction partner's project management organizations access to key design knowledge and decision making during the preliminary design engineering and planning processes. Construction issues and complexity is further reduced when the interests of all the stakeholders are aligned. Key stakeholders can include the owner/licensee, the investors and bankers, the A/E design and construction consortium partners and the major contractors.

Management oversight for engineering and construction therefore works best as a collaborative approach. The Atomic Alchemy management oversight team is led by an EPC firm that is not affiliated with either of Atomic Alchemy's design engineering or construction engineering A/E consortium partners, and initially begins during the final design stages of the entire facility. (Engineering and Construction management oversight for Phase 1 activities is not described in this position paper) The EPC oversight partner will bring significant experience and proven technical and administrative capability in overseeing nuclear construction projects or industrial projects of similar scope and complexity. The Phase 2 and Phase 3 oversight teams will also include members from the Atomic Alchemy Configuration Control Board Organization, as well as the Atomic Alchemy General Manager: Construction Services (GMCS), General Manager: Nuclear Process Operations (GMNPO), General Manager: Nuclear Reactor Operations (GMNRO), and the General Manager: Nuclear Design Engineering Services (GMNDES). All Atomic Alchemy general managers will report directly to the Atomic Alchemy Chief Nuclear Officer (CNO).

Project construction oversight activities will re-start with initiation of the Phase 2 and Phase 3 construction and end with turnover of the completed and commissioned Phase 2 or Phase 3 facility modules to Atomic Alchemy operations. Specific review procedural guidelines and training will be developed for the oversight teams. Development of management expectations promulgated through

[43] As part of phase 1 construction Atomic Alchemy will commit to submitting a "Functional Area and Baseline Inspection Readiness Report" (in accordance with the QAPD "Operational Readiness Assessment Program") for the Reactor and Radioisotope process modules, this will be identified as regulatory commitment AA0-RC-0018 in future docketed correspondence with the NRC.

these guidelines will describe the knowledge, skills, and abilities to be a successful subject matter expert on providing design and construction oversight. Emphasis will be placed on a graded approach to the level of safety significance and potential impact to the public health and safety of emerging issues that is clearly defined and consistently applied to avoid some of the current industry's weaknesses to construction-specific oversight which can often result in non-safety significant issues and safety significant issues being prioritized equally. Poor management construction oversight can lead to cost overruns and delays.

The preliminary scope of Atomic Alchemy engineering and construction oversight team for Phase 2 and Phase 3 will include:

a. Providing on-site liaison
b. Providing support in developing a Performance Improvement Program (PIP)[44]
c. Providing support to comptroller group to ensure funds are properly committed and obligated
d. Providing support to the test plan coordinators
e. Providing technical support to emergent situations, accidents, incidents etc. as required
f. Providing milestone readiness assessments
g. Providing benchmark project performance metrics against key performance standards
h. Providing additional support for all regulatory agency interfaces
i. Monthly review of project cost, schedule, and completion status
j. Monthly review of summary of external reports
k. Monthly joint oversight conference calls with project construction management
l. Bi-monthly review of Estimate-To-Complete (ETC) cost status
m. Bi-monthly monitoring of contractor and vendor performance metrics
n. Quarterly construction performance analysis
o. Quarterly construction cost and budget analysis
p. Delivering a quarterly status report to the Atomic Alchemy Board of Directors and other stakeholders

Effective project oversight leverages independent and objective perspectives to identify and manage risks. Risk is inevitable throughout a construction project's lifecycle, from design engineering, planning through construction, testing, and commissioning. Each phase presents a new set of challenges that can potentially create new risks.

15.0 SUMMARY/CONCLUSIONS

The effects of phased construction and testing activities of additional reactor or radioisotope processing modules on the safety functions of the operating modules in the facility will be evaluated for any potential adverse impacts in the CHA.

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[44] Performance Improvement will basically be a "lessons learned" program

The facility's configuration for operating VIPR(s) and radioisotope processes during construction will not be materially different than the configuration analyzed in the SAR, the independence of safety-related systems of each VIPR is maintained.

All shared systems (safety and non-safety) are partitioned at future tie in locations using the devices and mechanisms previously described in this position paper. All future shared components, piping, tubing, raceway, electrical conduits, and trays will be installed up to the future tie in points and will be properly maintained in good working order by administrative controls.

If the results of a construction deterministic safety assessment indicates that any construction related PIEs could lead to anticipated operational occurrences or to an accident condition then they will also be analyzed using the FSAR design basis accident rules, that is, demonstrating that they can be mitigated by the activation of safety systems and/or in combination with the previously prescribed operator actions.

The technical specifications specify the operational requirements for safety-related systems, which support safety system independence, single failure capability, and redundancy. In FSAR Chapter 15, Section 7.0, "Evaluation of Fault Sequences and Accident Scenarios," consequences of accidents that occur in a reactor module will be analyzed for their potential impact on the radioisotope process area and conversely accidents that occur in the radioisotope process area will be analyzed for their impact on any of the four operating reactors. Each respective technical specification LCO (either reactor or radioisotope process) will also include any necessary additional requirements in their respective LCO action statements to address faulted conditions occurring in other reactors or radioisotope systems and components.

Any potential shared system failures (safety related) are already considered as part of the Atomic Alchemy FSAR Chapter 15 safety analysis and covered by the T/S LCOs. Where these failures result in AOOs, they are included in the safety analysis either as a separate initiator, shown to be bounded by other analyzed transients, or bounded by the total failure of the component that the shared system served. The facility's safety analysis includes evaluations of shared system component failures up to and including total loss of the function of the shared system or components.

The design of the Atomic Alchemy facility complies with its PDC 5 which is based on 10 CFR 50, part 50 Appendix A General Design Criteria 5. VIPR safety related systems are functionally independent of each other, and do not share safety related systems with other reactors or radioisotope processes. The Phase 1 VIPR can operate in any of the 5 allowable T/S modes during Phase 2 construction, subsequently the two commissioned VIPRs can operate in any T/S allowable mode during Phase 3 construction activities.

The design of the Atomic Alchemy facility complies with Title 10 Part 50.34(a)(11). As provided in this position paper and as will be provided in FSAR Chapter 1, Appendix F, Atomic Alchemy describes the potential hazards created by construction activities on a multi-unit site, along with describing the advanced construction techniques, design features, administrative controls and management oversight that will be in place to ensure the continued safe operation of the previously commissioned units.

The design of the Atomic Alchemy facility complies with Title 10 Part 50.34(b)(6)(vii). As provided in this position paper and as will be provided in FSAR Chapter 1, Appendix F, Atomic Alchemy describes the potential hazards created by construction activities on a multi-unit site, along with describing the advanced construction techniques, design features, administrative controls and management oversight that will be in place to ensure that the continued operation of the previously commissioned units remain bounded by their technical specification limits and setpoints. The Construction hazards scoping study, along with the construction hazards analysis provides assurances that no PIE will result in a construction accident condition not bounded by the operating facility's SAR.

The design of the Atomic Alchemy facility complies with Title 10, Part 52.47(c)(3). As provided in this position paper and as will be provided in FSAR Chapter 1, Appendix F, Atomic Alchemy describes the configurations of the operating modules for specific construction and testing activities. Any temporary restrictions that may be necessary on operating modes of the VIPR(s) and/or radioisotope processes to permit certain construction or testing evolutions have been preliminarily addressed in this paper, they will subsequently be analyzed and clearly defined in the ITP. These potential configurations and administrative controls may include entering into specific Technical Requirements Manual TROs (i.e. TRO 3.0.2), utilizing OWAs, temporarily limiting the movement of reactor fuel, temporarily limiting the movement of radioisotope targets, capsules, and radioactive wastes, adding operators to the MCR, performing TRM program 5.6.1 safety function determinations prior to temporarily removing specific redundant trains from service, and lastly placing a VIPR and/or radioisotope production process train in a T/S mode of operation commensurable with the safety significance of a construction evolution.

This position paper has addressed Title 10, both Part 50 and Part 52 relevant regulatory requirements and it demonstrates for the staff and public a comprehensive outline plan of the construction strategies and innovative design approaches that will be used by Atomic Alchemy Inc. that will enable the safe construction, licensing, and operation of their Non-power Production Utilization Facility.

16.0 TABLES

Table 16.01 – Preliminary Shared Safety Related Radioisotope Process Systems

System
Plant Safety Related Instrument Air System
Pneumatic Conveying Capsule Tube Transport System
Radiation Monitoring and Alarm System
Operation and Control System
Class 1E Power System
Criticality Area Detection and Alarm System
Combustion Gas Monitoring System
Hot Cell Criticality Detection and Alarm System
Hot Cell Parameter Monitoring System
Class 1E DC and UPS Room Emergency Ventilation and Filtration System
Stairwell Pressurization Systems and subsystems
Smoke Exhaust/Purge Systems and subsystems
Off-Gas Treatment System and subsystems

Table 16.02 – Preliminary Shared Non-Safety-Related VIPR and Radioisotope Process Systems

System
Radioactive Waste Solidification System
Radioactive Waste Vitrification System
Building Management System
Cathodic Protection System
Communication and Data Systems (Wireless, PABX, Telephone, Wi-Fi)
Cyber Security Monitoring System
Closed Circuit TV System
Equipment and Floor Drainage System (Non-Radioactive)
Fire Protection Water System
Heating Water System
Heat Trace System
Main AC Power System
Material Handling System and subsystems
Miscellaneous Hot Cell Air Filtration Systems and Subsystems
Mo-99 Hot Cell Air Filtration Systems
Mo-99 Target, Production, Processing Module Air Filtration System
Mo-99 Target, Production, Processing Module HVAC System
On-site Stand-By Power System (Non-Safety)
Overhead Crane Systems
Plant Compressed Air System
Plant Instrument Air System (Non-Safety)
Plant Sampling System

Plant Gas Supply System
Plant Wet Vac System (Non-Radioactive)
Plant Lighting System
Plant Lightening and Grounding Protection System
Pneumatic Conveying Tube Transport System
Potable Water System
Process Production Module Re-Circulating Sensible Cooling/Heating System
Process Production HVAC Systems (1st and 2nd Floors)
Pneumatic Capsule Room Air Filtration System
Radioactive Liquid Waste Collection System
Radioactive Solid Waste Collection & Packaging System
Rad Waste Handling Module HVAC System
Rad Waste Handling Module Air Filtration System
Rad-Worker Radiation Permit System (Dosimetry Control)
Radioactive Gaseous Waste Collection System and Sub-systems
Roof Drain Collection System
Sanitary Sewer Drain System
Security Monitoring System
Shipping/Receiving HVAC System
Site Storm Drainage Collection System

17.0 FIGURES

Figure 17.01 General Facility Arrangement Depicting Construction Phases

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18.0 REFERENCES

American Society of Mechanical Engineers, 2017, NQA-1-2017, Part VI, Subpart 4.2.5, "Guidance on the Transition from Construction to Operation for Nuclear Facilities."

International Atomic Energy Agency, 2003 IAEA NS-G-1.5, "External Events Excluding Earthquakes in the Design of Nuclear Power Plant."

——— 2004, IAEA NS-G-1.7, "Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants."

——— 2011, IAEA NP-T-2.5, "Construction Technologies for Nuclear Power Plants."

——— 2015, IAEA SSG-38, "Construction for Nuclear Installations."

——— 2016, IAEA SSR 2/2, "Safety of Nuclear Power Plants: Commissioning and Operation."

——— 2020, IAEA 8-G, "Preventive and Protective Measures against Insider Threats."

——— 2020, IAEA 41-T, "Preparation, Conduct and Evaluation of Exercises for Detection of and Response to Acts Involving Nuclear and Other Radioactive Material out of Regulatory Control."

——— 2020, IAEA NG-T-1.6, "Management of Nuclear Power Plant Projects."

———2021, IAEA 10-G, Rev. 1, "National Nuclear Security Threat Assessment, Design Basis Threats and Representative Threat Statements."

———2021, IAEA 40-T, "Handbook on the Design of Physical Protection Systems for Nuclear Material and Nuclear Facilities."

International Energy Agency/Nuclear Energy Agency, 2014, "Lessons Learned from Recent New-Build Projects," IEA/NEA Nuclear Technology Stakeholder Engagement Workshop.

Nuclear Energy Institute, 2011, NEI 07-13, Rev 8P, "Methodology for Performing Aircraft Impact Assessments for New Plant Designs."

——— 2011, NEI 10-05, Rev. 0, "Assessment of On-Shift Emergency Response Organization Staffing and Capabilities."

———2005, NEI 04-04, Rev. 1 "Cyber Security Program for Power Reactors."

——— 2016, "Proposed Physical Security Requirements for Advanced Reactor Technologies," NEI White Paper.

U.S. Nuclear Regulatory Commission, 2012, NRC Inspection Manual Chapter IMC-2504, "Construction Inspection Program - Non-ITAAC Inspections."

———2013, NRC Inspection Manual Chapter IMC-2507, Procedure IP-37805, "Engineering Design Verification Inspections."

———2015, NRC Inspection Procedure IP-69022, "Inspections of Operational Readiness during Construction of Non-Power Production and Utilization Facilities."

U.S. Nuclear Regulatory Commission, 1978, NUREG-0396, “Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light-Water Nuclear Power Plants.”

——— 1992, NUREG-1367, “Functional Capability of Piping Systems.”

——— 2005, NUREG-1791, “Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m).”

U.S. Nuclear Regulatory Commission, 1979, NUREG/CR-0654, “Nuclear Power Plant Fire Protection - Fire-Hazards Analysis.”

——— 1983, NUREG/CR-1278, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications."

——— 1983, NUREG/CR-2254, "A Procedure for Conducting a Human Reliability Analysis for Nuclear Power Plants."

——— 1983, NUREG/CR-3330, “Vulnerability of Nuclear Power Plant Structures to Large External Fires.”

——— 1987, NUREG/CR-4772, "Accident Sequence Evaluation Program - Human Reliability Analysis Procedure."

——— 1997,NUREG/CR-6486, “Assessment of Modular Construction Structures at Power Plants for Safety-Related Advanced Nuclear Power Plants”.

——— 2014, NUREG/CR-7183, “Best Practices for Behavioral Observation Programs at Operating Power Reactors and Power Reactor Construction Sites”.

U.S. Nuclear Regulatory Commission, 2001, Regulatory Guide 1.78, Rev. 1, “Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release.”

——— 2012, Regulatory Guide 1.68.3, Rev 1, “Preoperational Testing of Instrument and Control Air Systems.”

——— 2013, Regulatory Guide 1.68 Rev. 4, “Initial Test Program for Water-Cooled Nuclear Power Plants.”

——— 2017, Regulatory Guide 1.28, Rev. 5 “Quality Assurance Program Criteria (Design and Construction).”

——— 2018, Regulatory Guide 1.206, Rev. 1, “Applications for Nuclear Power Plants.”

U.S. Nuclear Regulatory Commission, 2010, SECY-10-0034, “Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs,” March 28, 2010.

——— 2011, SECY-11-0098, “Operator Staffing for Small or Multi-Module Nuclear Power Plant Facilities,” July 22, 2011.

——— 2011, SECY-11-0152 “Development of an Emergency Planning and Preparedness Framework for Small Modular Reactor,” October 28, 2011.

——— 2018, SECY-18-0103, “Proposed Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies,” October 12, 2018.

——— 2018, SECY-18-0076, “Options and Recommendations for Physical Security for Advanced Reactors,” August 1, 2018.

Shanghai Nuclear Engineering Research and Design Institute Co., Ltd, 2“Lesson Learned of China AP1000.”

Westinghouse Electric Company, 2013, WCAP-16096-NP-A, Rev. 4, “Nuclear Safety Related Software Program Manual for Common Q™ Systems.”

——— 2012, “Construction Status/Lessons Learned Update AP1000® ITAAC Performance,” V.C. Summer New Nuclear Project Report presented at a public meeting, February 16, 2012.