Status Report - Pylon D1 (United States of America)

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1. Overview

☐ **In Operation**

☐ **Under Construction**

☐ **Described in**

Link to PRIS	--

☑ **New Concept**

Number of Units	--
Year	2027

Reference Plant

Name of Site	Will be located at the Demonstration of Microreactor Experiments (DOME) Facility at Idaho National Laboratory and will have a net power of 1 MWt.
Link to PRIS	--
Net Power Output (MWe)	--
Gross Power Output (MWe)	--

1.1 Introduction

Ultra Safe Nuclear Corporation (USNC) is developing the Pylon nuclear system architecture for research, transportable, and space applications. As a 10-ton class micro reactor, the Pylon architecture builds on Ultra Safe's Micro-Modular Reactor (MMR) and Fully Ceramic Microencapsulated (FCM) fuel technologies to be easily transportable and capable of safely generating electrical and thermal power anywhere.

As part of the Pylon product development process, USNC is pursuing the deployment of a derivative system, Pylon D1, for demonstration at the National Reactor Innovation Center (NRIC) Demonstration of Microreactor Experiments (DOME) facility at Idaho National Laboratory (INL). Demonstration will allow to validate the technology including licensability, performance, operations, safety, and cost.

1.2 Development Milestones

2022	Preliminary studies and technological innovation (using previously developed patents)
2023	Pre-conceptual design phase and technology validation
2024	Conceptual Design Phase
2026	Detailed Design Phases
2027	Procurement of Components and Acceptance Testing
2028	Assembly, Commissioning and Operation at NRIC DOME Facility
2030	Disassembly, Decommissioning, and Disposal

1.3 Design organization or vendor company

info@usnc.com

1.4 Links to designer/vendor website

https://www.usnc.com/pylon/

1.5 Design Description

The Pylon D1 Demonstration System contains a small, high-temperature gas-cooled reactor (HTGR) that utilizes Fully Ceramic Microencapsulated (FCM) nuclear fuel, metal hydride neutron moderator, and graphite control drums.

Pylon D1 uses helium as the working fluid to transfer the fission generated heat from the reactor via the primary coolant loop to a secondary supercritical CO_2 gas loop for rejection to the surrounding environment.

The overarching design philosophy maintains a very high degree of conservatism, coupled with a simple reactor plant design that enables reaching Pylon reactor demonstration goals. The demonstration is focused solely on reaching reactor power and temperature goals, without the expense, design, and safety analysis complexity of a coupled power generation balance of plant with grid connection.

The high-level goals for the Pylon D1 system are:

1. Achieve 1 MWth power
2. Achieve 1000 K reactor outlet temperature

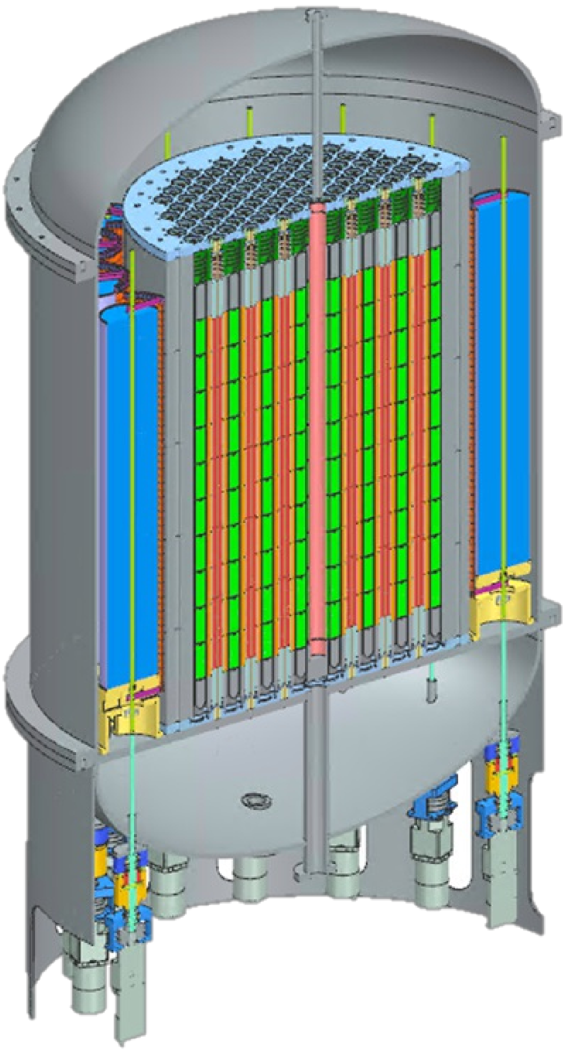

Figure 1. Pylon D1 system.

1.6 Licensing Application Support Documents

1.7 Reactor Unit in PRIS

2. Category Fields

Table 1: ARIS Category Fields

ARIS Category	Value	Units of Examples
Current/Intended Purpose	Demonstration	e.g. Commercial – Electric/Non-electric, Prototype/FOAK, Demonstration, Experimental
Main Intended Application (once commercial)	Off - grid / Remote	e.g. Baseload, Dispatchable, Off-grid/Remote, Mobile/Propulsion, Non-electric (specify)

Reference Location	Inland	e.g. On Coast, Inland, Below-Ground, Floating-Fixed, Marine-Mobile, Submerged-Fixed (Other-specify)
Reference Site Design (reactor units per site)	Single Unit	e.g. Single Unit, Dual Unit, Multiple Unit (# units)
Core Coolant	He	H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Reactor Core Size (1 core)	Thermal Power < 30 MWth	e.g. Thermal Power < 30 MWth, 30 MWth ≤ Thermal power < 1000 MWth, 1000 MWth ≤ Thermal power ≤ 3000 MWth, Thermal power > 3000 MWth
Reactor Type	GCR	e.g. PWR, BWR, HWR, SCWR, GCR, GFR, SFR, LFR, MSR, ADS
Reactor Size	Microreactor	e.g. PWR, SMR
Neutron Moderator	Other	e.g. H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
NSSS Layout	Loop-type	e.g. Loop-type (# loops), Direct-cycle, Semi-integral, Integral, Pool-type
Primary Circulation	Forced (1 pumps)	e.g. Forced (# pumps), Natural
Thermodynamic Cycle	Brayton	e.g. Rankine, Brayton, Combined-Cycle (direct/indirect)
Secondary Side Fluid	Other	e.g. H2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Fuel Form	Prismatic	e.g. Fuel Assembly/Bundle, Coated Sphere, Plate, Prismatic, Contained Liquid, Liquid Fuel/Coolant
Fuel Lattice Shape	Hexagonal	e.g. Square, Hexagonal, Triangular, Cylindrical, Spherical, Other, n/a
Rods/Pins per Fuel Assembly/Bundle	N/A	e.g. #, n/a
Fuel Material Type	Carbide	e.g. Oxide, Nitride, Carbide, Metal, Molten Salt, (Other-specify)

Design Status	Conceptual Design	e.g. Conceptual, Detailed, Final (with secure suppliers)
Licensing Status	DCR	e.g. DCR, GDR, PSAR, FSAR, Design Licensed (in Country), Under Construction (# units), In Operation (# units)
Neutron Spectrum	Thermal	e.g. Fast, Thermal

3. Parameter Fields

Table 2: ARIS Parameter Fields

ARIS Parameter	Value	Units of Examples
Plant Infrastructure		
Design Life		Years
Lifetime Capacity Factor	N/A	%, defined as Lifetime MWe-yrs delivered / (MWe capacity * Design Life), incl. outages
Major Planned Outages	N/A	# days every # months (specify purpose, including refuelling)
Operation / Maintenance Human Resources	TBD	# Staff in Operation / Maintenance Crew during Normal Operation
Reference Site Design	1	n Units/Modules
Capacity to Electric Grid	0	MWe (net to grid)
Non-electric Capacity	1 MWth @ 727°C	e.g. MW(th) heat at x °C, m3/day desalinated water, kg/day hydrogen, etc.
In-House Plant Consumption	0.025	MWe
Plant Footprint	500	m2 (rectangular building envelope)
Site Footprint	2000	m2 (fenced area)
Emergency Planning Zone	0	km (radius)
Releases during Normal Operation	0/0/0	TBq/yr (Noble Gases / Tritium Gas / Liquids)
Load Following Range and Speed	25 – 100%, 10%/minute	x – 100%, % per minute
Seismic Design (SSE)	TBD	g (Safe-Shutdown Earthquake)

NSSS Operating Pressure (primary side)	2	MPa(abs), i.e. MPa(g)+0.1, at core outlet
NSSS Operating Pressure (secondary side)	20	MPa(abs), i.e. MPa(g)+0.1, at secondary side outlet
Primary Coolant Inventory (incl. pressurizer)	4	kg
Nominal Coolant Flow Rate (primary)	0.36	kg/s
Nominal Coolant Flow Rate (secondary)	1.35	kg/s
Core Inlet Coolant Temperature	327	ºC
Core Outlet Coolant Temperature	727	ºC
Available Tempeature as Process Heat Source	727	ºC
NSSS Largest Component	RPV (empty)	e.g. RPV (empty), SG, Core Module (empty/fuelled), etc.
- NSSS Largest Component Length	1500	mm
- NSSS Largest Component Diameter	1650	mm
- NSSS Largest Component Thickness		mm
- NSSS Largest Component Weight	2	tonne
Reactor Vessel Material	SS316	e.g. SS304, SS316, SA508, 800H, Hastelloy N
Steam Generator Design	N/A	e.g. Vertical/Horizontal, U-Tube/ Straight/Helical, cross/counter flow
Secondary Coolant Inventory	200	kg
Pressurizer Design	N/A	e.g. separate vessel, integral, steam or gas pressurised, etc.
Pressurizer Volume	N/A	m3 / m3 (total / liquid)
Containment Type	Dry (single)	Dry (single/double), Dry/Wet Well, Inerted, etc.
Containment Volume	7500	m3

Spent Fuel Pool Capacity and Total Volume	N/A	Years of full-power operation / m3
Non Electric Application		-
Core Delta Temperature	400	ºC
Fuel/Core		
Single Core Thermal Power	1	MW(th)
Refuelling Cycle	30	months or “continuous”
Fuel Material	UCO	e.g. UO2, MOX, UF4, UCO
Enrichment (avg./max.)	9.9/9.9	%
Average Neutron Energy		eV
Fuel Cladding Material	TRISO	e.g. Zr-4, SS, TRISO, E-110, none
Number of Fuel “Units”	150 assemblies	Specify as Assembly, Bundle, Plate, Sphere, or n/a
Weight of one Fuel Unit	9.5	kg
Total Fissile Loading (initial)	370	kg fissile material (specify isotopic and chemical composition)
% of fuel outside core during normal operation	N/A	Applicable to online refuelling and molten salt reactors
Fraction of fresh-fuel fissile material used up at discharge	~0.25	%
Core Discharge Burnup	2.5	MWd/kgHM (heavy metal, eg U, Pu, Th)
Pin Burnup (max.)		MWd/kgHM
Breeding/Conversion Ratio		Fraction of fissile material bred in-situ over one fuel cycle or at equilibrium core
Reprocessing	None	e.g. None, Batch, Continuous (FP polishing/actinide removal), etc.
Main Reactivity Control	Drums	e.g. Rods, Boron Solution, Fuel Load, Temperature, Flow Rate, Reflectors
Solid Burnable Absorber	None	e.g. Gd2O3
Core Volume (active)	0.85	m3 (used to calculate power density)

Fast Neutron Flux at Core Pressure Boundary	200	n/(cm²*s)
Max. Fast Neutron Flux		n/(cm²*s)
Core Control Rod Absorber		-
Core Soluble Neutron Absorber		-
Safety Systems		
Number of Safety Trains	Active / Passive	% capacity of each train to fulfil safety function
- reactor shutdown	Active/Passive	100 / 100 / -
- core injection	N/A	- / - / -
- decay heat removal	N/A	- /- / -
- containment isolation and cooling	N/A	- / - / -
- emergency AC supply (e.g. diesels)	N/A	- / - / -
DC Power Capacity (e.g. batteries)	TBD	Hours
Events in which Immediate Operator Action is required	None	e.g. any internal/external initiating events, none
Limiting (shortest) Subsequent Operator Action Time	N/A	Hours (that are assumed when following EOPs)
Severe Accident Core Provisions	No core melt	e.g. no core melt, IVMR, Core Catcher, Core Dump Tank, MCCI
Core Damage Frequency (CDF)	0	x/reactor-year (based on reference site and location)
Severe Accident Containment Provisions	0	e.g., H2 ignitors, PARs, filtered venting etc.
Large Release Frequency (LRF)	0	x/reactor-year (based on reference site and location)
Overall Build Project Costs Estimate or Range (excluding Licensing, based on the Reference Design Site and Location)		
Construction Time (nth of a kind)	6	Months from first concrete to criticality
Design, Project Mgmt. and Procurement Effort	100	Person-years (PY) [DP&P]

Construction and Commissioning Effort	50	PY [C&C]
Material and Equipment Overnight Capital Cost	20	Million US$(2015) [M&E], if built in USA
Cost Breakdown	%[C&C]/%[M&E]	
- Site Development before first concrete		(e.g. 25/10) (30/40) (20/25) (20/10) (5/15) (-----------) (to add up to 100/100)
- Nuclear Island (NSSS)		
- Conventional Island (Turbine and Cooling)		
- Balance of Plant (BOP)		
- Commissioning and First Fuel Loading		
Factory / On-Site split in [C&C] effort		%/% of total [C&C] effort in PY (e.g., 60/40)
Nuclear System		
System Steam Flow Rate		kg/s
System Steam Pressure		MPa
System Steam Temperature		ºC
System Feedwater Flow Rate		kg/s
System Feedwater Temperature		ºC
Reactor Core		
Active Core Height		m
Equivalent Core Diameter		m
Average Linear Heat Rate		kW/m
Average Fuel Power Density		kW/kgU
Average Core Power Density	1.18	MW/m3
Outer Diameter Of Fuel Rods		mm

4. Plant Layout, Site Environment and Grid Integration

SUMMARY FOR BOOKLET

Pylon D1 will be installed in the Demonstration of Microreactor Experiments (DOME) facility at the Idaho National Laboratory (INL) Materials and Fuel Complex (MFC). System components will be skid mounted, allowing for construction and factory acceptance testing at an offsite USNC or vendor facility. System components will be shipped to the DOME facility where they will be inspected and connected. Primary and secondary loop working fluids will transfer heat to fluid-to-air heat exchangers outside the DOME facility. No cooling water will be required for operation of D1. Pylon D1's low power and use of TRISO fuel enables the reactor to be passively cooled within the DOME facility without the use of any external systems. The safety of collocated workers at INL's MFC and members of the public at the INL boundary will not be affected if cooling is lost to the reactor during operation. As a demonstration reactor, Pylon D1 will not be connected to a private or local electricity grid. Any power generated during operation will be converted to heat and transferred to the surrounding environment.

4.1 Site Requirements during Construction
4.2 Site Considerations during Operation
4.3 Grid Integration

5. Technical NSSS/Power Conversion System Designn

SUMMARY FOR BOOKLET

The Pylon D1 reactor and helium primary loop will operate within the EBR-II containment structure. A shielding structure housed within the containment structure will stop fast neutron and gamma radiation emitted from the reactor during and after operation. The helium primary loop will transfer heat from the reactor through penetrations in the shielding structure to the primary heat exchanger. The supercritical CO2 secondary loop will transfer heat from the primary heat exchanger through penetrations in the DOME containment structure for rejection to the surrounding environment.

The Pylon D1 reactor core consists of hexagonally-shaped fully ceramic microencapsulated (FCM) fuel elements. Each fuel element contains a centre annulus, into which a metal hydride moderator is placed to provide neutron moderation. The fuel elements are stacked vertically to create a fuel assembly. The fuel assemblies are arranged in a hexagonal array with spacing in between fuel elements to allow helium to flow and remove heat during operation. Axial and radial graphite reflectors are arranged around the reactor core to provide neutron reflection.

The FCM fuel elements consist of Tri-structural Isotropic (TRISO) nuclear fuel particles packed within a silicon carbide matrix. The silicon carbide within the fuel particles and the surrounding matrix serves as a very high temperature barrier to prevent release of radioactive fission products.

As a demonstration reactor, Pylon D1 is not designed for regular refuelling. To simplify handling of the fuel assemblies, assemblies with be tied together by upper and lower support plates. The support plates form six supercells that will can be lifted for shipping, storage, and disposal.

For reactor control and protection, Pylon D1 will use control drums placed within the radial graphite reflector. Each control drum contains a layer of boron carbide neutron absorber. To control the reactor, the boron carbide layer is rotated towards or away from the reactor core, changing the amount of neutron reflection occurring in the radial reflector. To provide a diverse and redundant method for reactor shutdown, a safety shutdown rod will be located at the centre of the reactor. The gravity-driven safety shutdown rod is raised using an electromagnetic coupler, which drops the rod into the reactor if power is lost or signal is given by the reactor protection system.

5.1 Primary Circuit

The Pylon D1 reactor and helium primary loop will operate within the EBR-II containment structure. A shielding structure housed within the DOME containment structure will stop fast neutron and gamma radiation emitted from the reactor during and after operation. The helium primary loop will transfer heat from the reactor through penetrations in the shielding structure to the primary heat exchanger.

5.2 Reactor Core and Fuel

The Pylon D1 reactor core assembly consists of a monolithic graphite structure, FCM fuel assemblies, and an upper and lower support plates. The graphite structure functions both as a neutron reflector and the primary structural support for the fuel assemblies. The fuel assemblies are combined in a prismatic hexagonal pattern to form the reactor core.

The reactor core is controlled through a series of control drums located in the radial graphite reflector and safe shutdown is assured with a redundant and independent safety shutdown rod at the reactor centreline.

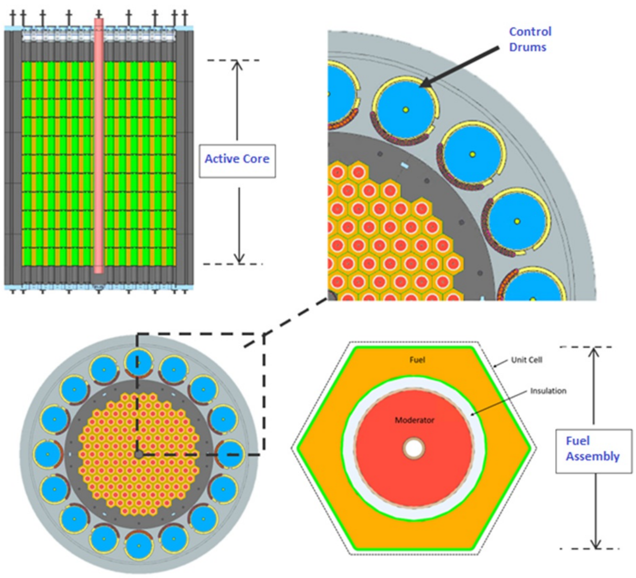

Figure 2. Conceptual arrangement of the Pylon D1 reactor and fuel assembly.

USNC has the capability to design and additively manufacture nuclear fuel, allowing rapid iteration to optimize for safety, performance, and reliability, starting with the fuel. The USNC additive manufacturing method, exclusively licensed for commercial applications from Batelle Energy Alliance, combines binder jet printing and chemical vapor infiltration in a process capable of yielding a high-purity, >93% dense ceramic matrix; attributes essential for high-performance nuclear fuel capable of retaining fission products in off-nominal conditions. Prototype fuel elements are currently under iteration at USNC's Pilot Fuel Manufacturing (PFM) Facility in Oak Ridge, TN, USA..

Figure 3. Additively manufactured, chemical vapor infiltrated SiC Pylon fuel element with prototypic size and shape and material. Filled with SiC surrogate powder.

The high TRISO packing fraction (>58%) enabled through this fuel manufacturing process enables Pylon to use 9.9% enriched uranium (LEU+) for fuel. This significantly de-risks the fuel supply chain. When commercial HALEU is available, USNC will have the option of fueling and/or refueling Pylon reactor cores with HALEU. This flexible approach enables USNC to take advantage of time to market and then to pivot to HALEU when readily available.

For fuel supply, USNC has signed a purchase agreement for 9.9% enriched uranium with Urenco USA with a first batch slated for delivery in 2025. The uranium will be delivered to USNC and Framatome's joint fuel factory. The joint USNC-Framatome Fuel factory will parallelize the existing fuel manufacturing process at USNC's operating PFM facility in Oak Ridge to manufacture Pylon fuel elements. After manufacturing, the fuel elements will be sent to the NRIC DOME facility for integration into the non-nuclear components of the Pylon D1 system.

5.3 Fuel Handling

As a demonstration reactor, Pylon D1 is not designed for regular refuelling. To simplify handling of the fuel assemblies, assemblies with be tied together by upper and lower support plates. The support plates form six supercells that will can be lifted for shipping, storage, and disposal.

5.4 Reactor Protection

For reactor control and protection, Pylon D1 will use control drums placed within the radial graphite reflector. Each control drum contains a layer of boron carbide neutron absorber. To control the reactor, the boron carbide layer is rotated towards or away from the reactor core, changing the amount of neutron reflection occurring in the radial reflector. To provide a diverse and redundant method for reactor shutdown, a safety shutdown rod will be located at the centre of the reactor. The gravity-driven safety shutdown rod is raised using an electromagnetic coupler, which drops the rod into the reactor if power is lost or signal is given by the reactor protection system.

Fission product retention in the Pylon D1 reactor starts at the fuel. The FCM fuel elements consist of Tri-structural Isotropic (TRISO) nuclear fuel particles packed within a silicon carbide matrix. The silicon carbide within the fuel particles and the surrounding matrix serves as a very high temperature barrier to prevent release of radioactive fission products.

5.5 Secondary Side

The supercritical CO2 secondary loop will transfer heat from the primary heat exchanger through penetrations in the DOME containment structure for rejection to the surrounding environment. USNC has partnered with Peregrine Turbine Technologies (PTT) for development of the supercritical CO2 secondary loop.

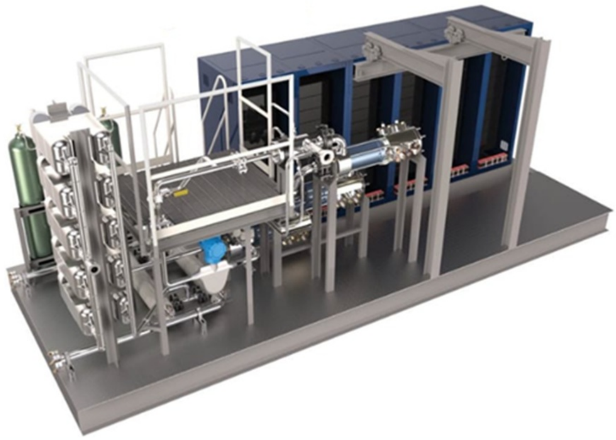

Figure 4. PTT’s Advanced Closed-Cycle Merlin 1MW Turbine Engine for Ground-Based Power.

5.6 Containment/Confinement

Pylon D1 will be operated within the DOME facility at Idaho National Laboratory. The DOME facility is a reuse of the Experimental Breeder Reactor II (EBR-II) containment. The interior of the containment dome is 25 m tall and 21 m diameter.

Figure 5. Exterior view of EBR-II containment, the key structure composing the DOME facility.

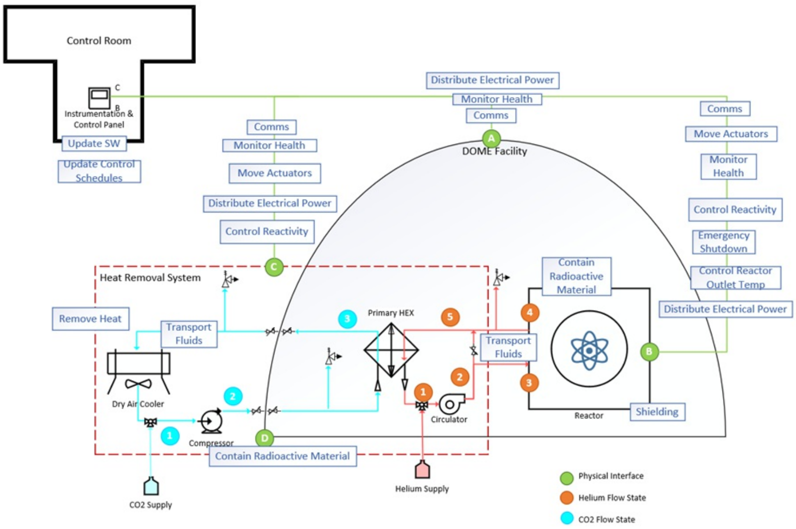

Figure 6. Key Interfaces and Functions of the Pylon D1 System within the DOME Facility.

5.7 Electrical, I&C and Human Interface
5.8 Unique Technical Design Features (if any)

6. Technology Readiness

SUMMARY FOR BOOKLET

To enable operation of Pylon D1, Idaho National Laboratory will submit licensing documentation to the US Department of Energy (DOE) for review and approval. USNC and Idaho National Laboratory have executed a contract to complete the Front-End Engineering and Experiment Design (FEEED), at the end of which will result in the submission of the Safety Design Strategy (SDS) and Conceptual Safety Design Report (CSDR). At this time the SDS has been submitted for review and submission of the CSDR is expected in August 2024. Additionally, as part of FEEED, USNC will undergo a quality assurance audit to show compliance with a subset of ASME NQA-1 standards. Due to Pylon D1's small size and skid mounted architecture, Pylon D1 will be factory assembled and shipped to the operations site following factory acceptance testing. Lessons learned in the design, construction, operation, and decommissioning of Pylon D1 will influence the production of later Pylon versions for commercial operation. Later versions of Pylon will have increased performance targets (power, temperature, size, mass) and improved cost targets. Future versions of Pylon will have equivalent or smaller size to Pylon D1, allowing continued factory production. Factory production of Pylon systems will allow very high levels of standardization for deployed plants with greatly reduced construction times. Future versions of Pylon will require different levels of reliability and maintainability for systems and equipment.

6.1 Deployed Reactors

6.2 Reactors under Licensing Review
6.3 Reactors in the Design Stage

7. Safety Concepts

SUMMARY FOR BOOKLET

The safety concept for Pylon D1 is based on the high temperature capability of FCM nuclear fuel, its small size, and its control scheme. FCM fuel leverages the intrinsic properties of silicon carbide, both in the TRISO particle and in the fuel matrix to prevent the release of fission products from the nuclear fuel. With a reactor outlet temperature of 727 °C, the peak fuel temperature can be kept far below the fuel safety limit of 1600 °C. Pylon D1's small size means the reactor has a high surface area to volume ratio. Fission product decay heat is conducted into the graphite radial reflector to the reactor pressure vessel. The heat can then be convected and radiated to the surrounding shielding and containment structure. Pylon D1's uses two diverse and redundant methods for insuring shutdown. The control drums arranged in the radial reflector, and a centre safety shutdown rod. The centre safety shutdown rod, which is fully removed from the reactor during operation, contains enough worth to overcome the worth of the control drums during the reactor lifetime. The control drums will also automatically insert in the event of a reactor trip. The action of either control system will insure reactor shutdown. Pylon D1 leverages multiple defense-in-depth features including a helium purification system, an ASME-rated primary loop pressure boundary, the DOME confinement building, and an operation location with significant distance from population. By relying on FCM fuel and its small size, Pylon D1 can remove all heat related safety systems, allowing for greater simplicity and increased robustness. No operator action is required in abnormal or accident conditions. Control systems will insert upon trip of the reactor protection system. Heat will transfer to the surrounding shielding and containment structures. Radioactive fission products will be contained within the FCM fuel. Fast neutron and gamma radiation will be blocked by the external shielding structure.

7.1 Safety Philosophy and Implementation

The safety goals in nuclear facility design and operation are to ensure adequate protection of the public, workers, and environment. A primary assumption for the protection of the public, workers, and environment is to use inherently safer design concepts in the reactor designs with a performance-based graded approach. In a general sense, the performance-based approach can be summarized by identifying four Fundamental Safety Functions (FSFs): 1) reactivity control, 2) heat removal, 3) radioactive material retention, and 4) shielding. The control reactivity and remove heat functions are typically necessary to prevent conditions that would challenge temperature and pressure design limits of the radionuclide confinement barriers and preserve the barrier's integrity. The Pylon D1 design will ensure that these fundamental safety functions are satisfied through a combination of Structures, Systems, and Components (SSCs) with appropriate safety classification and associated evaluations for adequacy of Defense-in-Depth (DID) based on the reactor hazard analysis.

Pylon D1 uses independently operated control drums located in the radial reflector, which contain mechanisms to fail-safe in the event of a loss of power, to control reactivity. Pylon D1 also uses a gravity-driven safety shutdown rod, providing a redundant, independent, and fail-safe form of reactor shutdown in the event of loss of power. The fuel, metal hydride moderator, and reflectors all behave differently (in terms of reactivity) as temperature increases. However, the net result is that the system always exhibits a safe negative temperature reactivity behaviour due to the metal content and fuel arrangement.

Pylon D1 uses FCM Fuel, which contains robust silicon carbide radionuclide barriers. These barriers start with the use of AGR-based TRISO particle fuel, which are then encapsulated in a fully ceramic silicon carbide matrix. A fuel safety case technical report will be developed and delivered alongside submission of the preliminary documented safety analysis (PDSA). Operational temperatures will be limited to hundreds of degrees centigrade below fuel safety limits to provide additional safety margin, to be verified during test. A central component to a layered approach is the use of successive, multiple physical barriers for protection against release of radioactivity and hazardous materials. Beyond the FCM fuel providing layers of protection against the release of fission products, the American Society of Mechanical Engineers (ASME)-rated primary coolant boundary (Reactor Pressure Vessel (RPV) and piping) provides an additional barrier for radionuclide retention.

Pylon D1 will use helium as a primary coolant to transfer heat from the reactor core to the primary heat exchanger, however the primary coolant will not be necessary for heat removal in loss of forced coolant events. The low power of Pylon D1, its small size, and use of high temperature capable AGR-based TRISO particle fuel enable decay heat to be conducted to the surface of the RPV and rejected to the ambient environment through natural convection and radiation, even with additional shielding installed.

For shielding, Pylon D1 will utilize shielding that will work in conjunction with the radial and axial neutron reflectors to reduce neutron and gamma radiation to the surrounding environment. The shielding will also reduce activation of the reactor pressure vessel and nearby components, aiding in decontamination and decommissioning. Pylon D1 electrical components, such as the controller and motors, may have shielding to allow the components to remain functional. Operation of Pylon D1 will take place within a shielded structure within the DOME test bed.

The selection of reactor-specific SSCs in the addendums follows the hierarchy of controls listed in DOE-STD-1189-2016, such that safety SSCs are derived based on the following order of preference:

1. SSCs are preferred over administrative controls.

2. Passive SSCs are preferred over active SSCs.

3. Preventive controls are preferred over mitigative controls.

4. Controls closest to the hazard may provide protection to the largest population of potential receptors, including workers and the public.

5. Controls that are effective for multiple hazards can be resource effective.

The safety goals will also be fulfilled by an approach that ensures adequate DID by providing multiple independent layers of protection to prevent the release of radioactive and hazardous materials or, if prevention fails, to limit the potential consequences of accidents and to prevent their evolution to more serious conditions. The DOE philosophy for DID is best summarized in DOE G 420.1-1A, “Nonreactor Nuclear Safety Design Guide for use with DOE O 420.1C, Facility Safety.”10 Section 7 discusses what DOE guidelines Pylon will follow for hazard identification while operating at DOME.

The Pylon D1 design approach will adopt the five levels of DID in the DOE G 420.1-1A guidance to ensure adequate plant capability DID in the reactor design:

Level 1: Prevention of abnormal operation and failures

Level 2: Control of abnormal operation and detection of failures

Level 3: Control of accidents within the design basis

Level 4: Control of severe facility conditions

Level 5: Mitigation of radiological consequences

7.2 Transient/Accident Behaviour

No operator action is required in abnormal or accident conditions. Control systems will insert upon trip of the reactor protection system. Heat will transfer to the surrounding shielding and containment structures. Radioactive fission products will be contained within the FCM fuel. Fast neutron and gamma radiation will be blocked by the external shielding structure.

8. Fuel and Fuel Cycle

SUMMARY FOR BOOKLET

The fuel source for the Pylon D1 reactor will be a fully encapsulated, TRISO-coated Uranium Oxycarbide (UCO) kernel. The UCO kernel will be 500 µm in diameter and 9.9% enriched. The UCO kernel will be coated with successive layers of buffer, inner pyrolytic carbon, silicon carbide, outer pyrolytic carbon. The multiple layers around the UCO kernel act as the fission product retention barrier throughout the fuel lifetime. The TRISO particle used in the Pylon D1 reactor is the same design used in USNC's MMR Chalk River Project and will be produced alongside them in the planned fuel production factory operated by the USNC/Framatome JV. UCO was chosen for Pylon ground demonstration because the fuel is available and there is fuel performance data available under the AGR testing program. The fuel performance data in the EPRI report "locks-in existing fuel performance data and results in a form that can increase the efficiency of the safety review process for design certification and licensing applications in the United States and internationally." The TRISO parameters are consistent with the AGR TRISO fuel tested.

8.1 Fuel Cycle Options
8.2 Resource Use Optimization
8.3 Unique Fuel/Fuel Cycle Design Features

9. Safeguard & Physical Security

SUMMARY FOR BOOKLET

The safeguards category for Pylon D1 is Category IV, as defined in DOE O 474.2, “Nuclear Material Control and Accountability.” Pylon D1 uses 9.9% enriched fuel, and the project is considered unclassified commercial official use only. The appropriate material control and accountability requirements will be met in accordance with applicable INL management control procedures with the design and construction considerations.

An appropriate security plan will be completed and approved prior to the start of construction (including site preparation), consistent with DOE O 470.4B, “Safeguards and Security Program.” The plan will include controlled access by authorized and trained personnel and is not expected to affect the design or safety aspects of the reactor or the facility. The plan will be updated as appropriate to reflect changes made affecting security.

9.1 Safeguards

The safeguards category for Pylon D1 is Category IV, as defined in DOE O 474.2, “Nuclear Material Control and Accountability.” Pylon D1 uses 9.9% enriched fuel, and the project is considered unclassified commercial official use only. The appropriate material control and accountability requirements will be met in accordance with applicable INL management control procedures with the design and construction considerations.

9.2 Security

An appropriate security plan will be completed and approved prior to the start of construction (including site preparation), consistent with DOE O 470.4B, “Safeguards and Security Program.” The plan will include controlled access by authorized and trained personnel and is not expected to affect the design or safety aspects of the reactor or the facility. The plan will be updated as appropriate to reflect changes made affecting security.

9.3 Unique Safeguards and/or Security Features

10. Project Delivery & Economics

SUMMARY FOR BOOKLET

To operate the Pylon D1 reactor, USNC will work with INL to integrate within the DOME facility. To allow the reactor to operate within the DOE authorization structure, INL will function as the design authority. In this arrangement, USNC will transfer design basis documentation to INL for finalization and approval. Operators for Pylon D1 will train under INL supervised training programs.

Overnight capital cost for the Pylon D1 system is estimated overnight capital cost of $20 million. Funding for the Pylon D1 system will be provided entirely by USNC as part of development cost for the Pylon nuclear system product.

10.1 Project Preparation and Negotiation

To operate the Pylon D1 reactor, USNC will work with INL to integrate within the DOME facility. To allow the reactor to operate within the DOE authorization structure, INL will function as the design authority. In this arrangement, USNC will transfer design basis documentation to INL for finalization and approval. Operators for Pylon D1 will train under INL supervised training programs.

10.2 Construction and Commissioning

Overnight capital cost for the Pylon D1 system is estimated overnight capital cost of $20 million. Funding for the Pylon D1 system will be provided entirely by USNC as part of development cost for the Pylon nuclear system product.

10.3 Operation and Maintenance