Engineering a Factory-Manufactured 10 MWe Integral PWR for India

Daratha Atomics | Technical Thesis and Engineering Basis | September 2026

ABSTRACT

India's nuclear energy build-out creates a rare engineering opportunity: combine a mature reactor technology with a product architecture designed for repeat manufacturing. Daratha Atomics is developing a factory-manufactured 10 MWe / 32 MWt Integral Pressurized Water Reactor (IPWR) using light-water PWR technology and standard low-enriched UO_2 fuel. Following internal technical review, the design has been re-baselined around an integral configuration in which the core, helical steam generators, canned-motor primary pumps and pressurizer are contained within a single reactor pressure vessel. This paper summarizes the current technical basis, the engineering evidence still required, and the path from design to a licensable, manufacturable first-of-a-kind reactor.

1. INTRODUCTION

India has spent decades building nuclear science, operating experience, engineering capability and a domestic industrial base. The sector is now entering a new phase: private participation has opened under the SHANTI Act, while national policy targets approximately 22 GW by 2032 and 100 GW by 2047. The opportunity is therefore to build on that foundation with new reactor products, manufacturing systems and companies.

Daratha's thesis is that at microreactor scale, more of the complexity can move from a site-specific megaproject into a standardized product and controlled manufacturing environment. Site works, security, heat rejection, grid or customer integration and licensing remain, but the reactor itself can be engineered for repetition rather than redesign.

1.1 Technology selection as risk allocation

Fusion, molten-salt reactors, fast reactors, high-temperature gas-cooled reactors and thorium fuel cycles may all become important. Daratha's first product deliberately avoids stacking several new technology risks at once. PWR technology offers mature physics, materials, coolant behaviour, safety-code infrastructure and operating experience. The objective is not to invent new reactor physics; it is to engineer proven physics into a compact, transportable and repeatable product.

The 10 MWe scale is a product and engineering hypothesis that must continue to be tested against customer load profiles, redundancy, transportability, staffing, refuelling, thermal efficiency, capital cost and factory throughput. The current baseline gives the Design team a concrete architecture against which those trade-offs can now be measured.

2. POST-REVIEW TECHNICAL BASELINE

The Daratha design team has re-baselined the commercial target around a 10 MWe / 32 MWt Integral PWR. Previous loop-type PWR concepts and the earlier 50 MWt demonstration placeholder are superseded for the current baseline. The primary system integrates the reactor core, four helical steam generators, four canned-motor primary pumps and the pressurizer within a single RPV, eliminating external primary loop piping from the baseline architecture.

2.1 Core physics and reactivity control

Parameter	Current baseline
Core layout	16 fuel assemblies in a 4 x 4 square lattice
Fuel assembly	15 x 15 lattice; 204 fuel pins + 21 guide/control tubes per assembly
Total fuel pins	3,264
Fuel	UO_2, 4 wt% U-235
Heavy metal inventory	1.744 tHM
Active fuel length	1.10 m
Equivalent core diameter	0.893 m
Core volume	0.689 m3
Soluble boron	0 ppm baseline
Burnable absorber	Candidate: 12 pins/assembly with 4.0 wt% Gd_2O_3; requirement still under review
Control rods	12 RCCAs; current design target SDM >5.5% delta-k/k with highest-worth rod stuck out

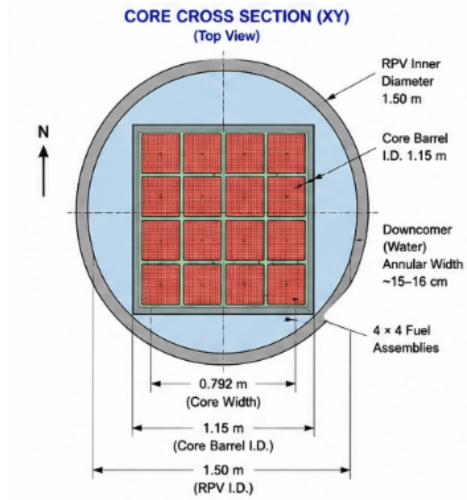

Figure 1. Daratha 4 x 4 fuel-assembly core arrangement retained in the current 10 MWe / 32 MWt baseline.

The zero-soluble-boron strategy is intended to simplify the factory-sealed microreactor concept and reduce dependence on complex chemical-volume-control water processing. The technical team's present candidate uses integral gadolinia burnable absorber plus RCCAs, but the need for burnable absorber remains an open design decision and will be finalized through detailed neutronic optimization.

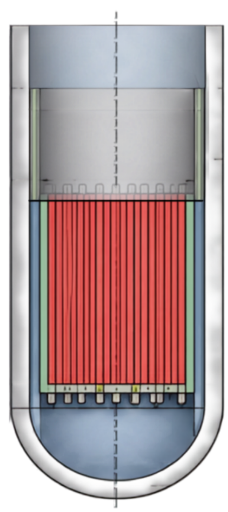

Figure 2. Daratha core and vessel-internals development rendering. Final IPWR internals remain subject to detailed mechanical and neutronic design.

2.2 Thermal-hydraulic basis

Variable	Current baseline
Primary pressure	15.5 MPa
Core inlet / outlet	285^{0}C / 320^{0}C
Core mass flow	157.2 kg/s
Average LHGR	8.91 kW/m
Maximum design LHGR	27.8 kW/m
F_Q	3.12 (F_{xy} 1.84; F_z 1.70)
F_{dH}	1.55
Hot-channel mass velocity	2,185 kg/m^2-s
Operating peak heat flux	93.15 W/cm^2
Calculated local CHF	180.7 W/cm^2
Current calculated MDNBR	1.94

These values form the current design-team baseline, not a completed safety case. The MDNBR result is a present engineering calculation using a Tong / W-3 correlation and will need to be independently verified, uncertainty-bounded and reconciled with the final fuel, geometry, power distribution and licensing methodology.

3. INTEGRAL ARCHITECTURE, TRANSPORTABILITY AND THE ENGINEERING PROBLEM

3.1 Integral primary system

Our IPWR design reduces external primary piping in RPV and changes the loss-of-coolant accident spectrum relative to a conventional loop-type PWR. It also creates new coupled constraints: RPV diameter, internal arrangement, steam-generator performance, pump maintainability, instrumentation penetrations, shielding, natural-circulation behaviour and manufacturability must all close within one pressure boundary.

3.2 Transportability envelope

Transportability is now an explicit design input rather than a downstream logistics problem. The current technical baseline targets an RPV envelope of 3.15 m outer diameter, 9.20 m overall height and approximately 78 metric tonnes dry transport mass. The design team has benchmarked these dimensions against stated Indian road and rail over-dimensional-cargo envelopes; the specific route, carrier, axle configuration and regulatory approvals will still require project-level validation.

Parameter	IPWR target	Current referenced envelope	Indicative margin
RPV outer diameter	3.15 m	3.50 m	0.35 m
Overall vessel height	9.20 m	9.50 m	0.30 m
Dry transport mass	78 MT	95 MT	17 MT

3.3 The binding engineering constraint

The design problem is not simply to make a conventional IPWR smaller. Miniaturization increases neutron leakage while compact integration tightens thermal, mechanical and shutdown-margin constraints. The same geometry must satisfy core physics, heat removal, pressure-boundary design, transportability, inspection, maintenance and nuclear-grade manufacturing. A change that improves one variable can worsen another.

The next optimization cycle therefore needs to treat enrichment distribution, burnable absorber loading, RCCA worth, power peaking, flow distribution, steam-generator duty, pump performance, vessel geometry and transport envelope as a coupled system rather than independent calculations.

3.4 What remains to be proven

Domain	Evidence required next
Neutronics	Validated depletion, rod worth, stuck-rod cases, coefficients, xenon, power distributions, shutdown margin
Thermal hydraulics	Subchannel / CFD verification, pressure drop, CHF/DNBR uncertainty, transients, natural circulation and decay heat
Mechanical / RPV	Code-class sizing, internals loads, penetrations, inspection access, seismic and transport loads
Integral system	Pump and HSG performance, primary-secondary coupling, control response, maintainability and failure modes
Transportability	Route-specific dimensional/mass validation, lifting and handling analysis, shipment configuration
Safety / licensing	DBA/DEC analysis, PSA, QA, configuration control and regulator engagement

4. SAFETY, VALIDATION AND LICENSING PROGRAM

The most important output of the next phase is a traceable body of evidence showing why the design behaves safely, where its margins come from, how sensitive those margins are to uncertainty and how the design evolves under configuration control. The design will also be subjected to various simulations and testing to ensure its robustness. Also this may include getting a certification/validation from external vendors.

4.1 The 18-24 month engineering program

Daratha's current ₹20 crore pre-seed plan is a technical risk-retirement program. The approved technical baseline concentrates capital on the analyses and validation infrastructure needed to move from engineering calculations toward a preliminary safety case and structured pre-licensing engagement.

Engineering domain	Indicative allocation	Primary work
Core neutronics & physics	₹3 Cr	Optimize Gd2O3 / absorber strategy; RCCA worth; depletion and power distributions using OpenMC / Serpent or equivalent
Thermal hydraulics & CFD	₹6 Cr	Subchannel modelling; W-3 MDNBR verification; flow distribution; natural circulation and decay heat using OpenFOAM / COBRA-IV or equivalent
Safety analysis & code setup	₹7 Cr	LOCA / LOFA and other event modelling; Level-1 PSA using RELAP5 / TRACE or equivalent
Validation, QA & regulatory readiness	₹4 Cr	Independent verification, experimental planning, configuration control, QA, documentation and pre-licensing support

4.2 Prototype and validation philosophy

A non-fueled integrated engineering prototype can retire a different class of risk from computation: pump behaviour, pressure drop, flow distribution, heat-transfer hardware, controls, instrumentation, maintainability and assembly sequence. It cannot validate reactor physics, but it can test whether the integrated product behaves mechanically and thermally as the models predict.

The engineering loop is: model -> simulate -> build -> test -> compare with prediction -> invalidate or validate assumptions -> iterate -> document. The objective is to progressively replace assumptions with evidence.

4.3 Regulatory alignment

Daratha is designing for regulatory engagement from the beginning rather than treating licensing as a final-stage exercise. The company will need to establish the applicable design codes, safety classification, analysis methodology, QA system, liability and ownership structure, fuel and material controls, and the evidence package expected by AERB and other relevant authorities. Regulatory familiarity is one reason the first product uses a light-water PWR architecture, but familiarity does not reduce the requirement for design-specific evidence.

5. TEAM AND EXECUTION ADVANTAGE

Building a nuclear energy company requires more than reactor physics. The same organization must integrate reactor engineering, safety, regulation, manufacturing, suppliers, capital and customers. Daratha is being built around those intersections.

The technical foundation includes Rajat Pandey, Head of Nuclear Engineering, with more than 25 years of nuclear engineering experience and contribution to the Indian Navy's INS Arihant nuclear submarine programme, together with senior nuclear-safety capability and advisors including former AERB Vice Chairman S. Duraisamy and former NPCIL leaders R.K. Saraogi and A.S. Mathur. The company-building team brings experience across energy, engineering, entrepreneurship, finance, operations and capital formation.

5.1 Our unfair advantage

Daratha's unfair advantage, if we earn it, will not be one isolated patent or credential. It will be the compounding capability to integrate nuclear engineering, regulatory execution, supplier qualification, manufacturing, capital and customer requirements inside one company. Established nuclear organizations have deep engineering capability; startups can move quickly and attract risk capital. Daratha's goal is to combine the strengths required from both worlds and build a new generation of nuclear engineering talent around the program.

While the reactor is the product, the durable advantage should become the engineering, regulatory and manufacturing system that allows the company to improve and reproduce it.

5.2 Building the organization

Capability	Core functions as the company scales
Reactor engineering	Chief Reactor Engineer / CTO; neutronics; thermal hydraulics; mechanical / RPV; fuel and materials; steam generation; I&C; systems engineering
Safety & licensing	Nuclear safety; deterministic accident analysis; PSA; QA; configuration management; regulatory affairs
Industrialization	Manufacturing engineering; supplier qualification; nuclear-grade QA; test engineering; supply chain; field deployment
Company building	CEO / product leadership; finance and project finance; commercial / customers; government affairs; talent and training

The objective is not to own every capability from day one. It is to know which capabilities must sit inside Daratha, which can be developed with qualified partners, and which evidence must remain under Daratha's design authority and configuration control.

6. FROM REACTOR DESIGN TO NUCLEAR ENERGY COMPANY

6.1 Technology, policy and economics

Daratha succeeds only if three vectors converge. A technically elegant reactor that cannot be licensed is not a product. A licensable reactor that cannot produce competitive power is not a business. An economically attractive concept that cannot satisfy nuclear safety requirements will never leave the drawing board. Product decisions therefore have to be made simultaneously through technology, policy and economics.

6.2 Capital should follow progressive evidence

The ₹20 crore program is the first major technical and regulatory de-risking layer. Later capital should follow increasingly concrete evidence: validated models, prototype data, supplier quotations, regulator feedback, detailed engineering and a credible construction plan.

Daratha's current internal planning assumption places the first-of-a-kind journey at approximately US$100 million order of magnitude. This is a preliminary top-down cost envelope, not a vendor-quoted EPC estimate.

FOAK cost area	Current indicative assumption
Design, engineering, safety & regulatory readiness	~₹20 Cr
Site & pre-project infrastructure	~₹5-10 Cr
Nuclear island	~₹180-200 Cr
Balance of plant, equipment, construction, execution & commissioning	~₹630-650 Cr
Indicative pre-tax project envelope	~₹835-880 Cr
Taxes / other project costs	Additional
Current FOAK order of magnitude	~US$100M

As the architecture matures, these assumptions should be replaced by component-level bills of material, supplier quotations, manufacturing estimates, site-specific construction costs and commissioning requirements. FOAK is not the economic end state; the manufacturing thesis depends on reducing engineering, procurement, construction and commissioning cost through repetition.

6.3 Manufacturing and deployment model

Daratha's long-term objective is to standardize not only the reactor design but how it is manufactured and deployed. The ambition is to move as much work as practical into a controlled factory environment, where components and modules can be manufactured, assembled, tested and quality-controlled repeatedly before site delivery.

Factory manufacturing requires qualified materials and suppliers, controlled fabrication processes, component testing, nuclear-grade QA, traceability, specialized tooling and trained personnel. Daratha is beginning to map these requirements across the manufacturing chain while determining which capabilities should ultimately sit inside the company and which should be developed with qualified manufacturing partners. Earlier assumptions such as 70-80% factory completion and 3-6 month on-site construction remain ambitions to be validated, not performance commitments.

7. CONCLUSION

Daratha is not waiting for a breakthrough in physics. The company is attempting a different kind of engineering challenge: take mature light-water PWR technology and turn it into a compact, transportable, factory-manufactured 10 MWe product.

The post-review baseline makes that challenge substantially more concrete. The current design is a 10 MWe / 32 MWt IPWR with 16 fuel assemblies, 3,264 fuel pins, 1.744 tHM of 4 wt% enriched UO_2, an integral primary system, four helical steam generators, four canned-motor pumps, a zero-soluble-boron baseline and an RPV sized around an explicit transportability envelope. The design team has also established a current thermal-hydraulic calculation basis, including a calculated MDNBR of 1.94, while clearly identifying the analyses and validation still required before these values can become licensing evidence.

The next 18-24 months are about converting the present baseline into evidence: detailed neutronics, thermal hydraulics, safety analysis, mechanical design, prototype testing, QA, supplier engagement and regulator-facing documentation. That is what the current pre-seed capital is intended to buy.

If those loops close, the opportunity is larger than a single reactor. The deeper asset will be an organization capable of repeatedly integrating nuclear engineering, regulation and manufacturing into a standardized nuclear energy platform for India and, eventually, other markets.

REFERENCES

[1] Daratha Atomics Design Team, 'Technical Design Basis for a Factory-Manufactured 10 MWe Integral PWR (IPWR): Core Physics, Thermal-Hydraulics, Transportability Envelope, and Regulatory Alignment,' Baseline Version 2.0 (Post-Review Re-Baseline), September 2026.

[2] KPMG in India / USIBC, 'Atoms for net-zero: A 100 GW bet on India's nuclear expansion ambitions through private-sector participation,' March 2026.

[3] Government of India, Department of Atomic Energy / Press Information Bureau, Nuclear Energy Mission and 100 GW by 2047 policy materials, 2026.

[4] U.S. Nuclear Regulatory Commission, light-water microreactor pre-application materials; and U.S. Department of Energy advanced nuclear / microreactor program materials.

Note: All design values in this paper reflect the September 2026 post-review baseline and remain subject to detailed engineering, independent verification, validation and regulatory review.