European Quantum Hardware Mergers: Scale Economics versus Modality Diversification

A Transaction Framework for Shared Infrastructure, Independent Technology Paths and Evidence-Based Value

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Abstract

European quantum-hardware mergers are often justified by a shortage of scale. Fabrication, cryogenics, photonics, lasers, control electronics, test infrastructure, specialist talent and public procurement all require capital that a small company may struggle to finance alone. A combination can spread those costs across a larger programme. It can also join technical paths whose physical constraints, development cycles and evidence standards remain fundamentally different. The transaction decision therefore concerns the quality of shared scale and the value of preserving independent modality options.

This paper develops an evidence-led M&A framework for European quantum-hardware transactions. It distinguishes same-modality horizontal consolidation, adjacent-capability vertical acquisition and cross-modality portfolio combination. It compares superconducting, trapped-ion, neutral-atom and photonic approaches through the deal questions they create, maps shared inputs and duplicated capital, tests intellectual-property and talent dependency, and integrates competition review, foreign-investment screening, export controls, public procurement and state-supported infrastructure into valuation and transaction design.

The evidence includes the European Commission's Quantum Europe Strategy, EuroHPC's multi-technology procurement programme, the European Patent Office and OECD study of the global quantum ecosystem, the European Commission's draft 2026 Merger Guidelines, UK quantum policy, ISO and NIST measurement work, public information concerning IonQ's acquisition of Oxford Ionics, Pasqal's acquisition of AEPONYX and IQM's 2026 public-market transaction. These sources show an ecosystem with several competing modalities, substantial public involvement and an unresolved scale-up financing gap. Company announcements are identified as company-reported information and are not treated as independently verified operating results.

A wholly hypothetical transaction illustrates the method. A European quantum-hardware group considers acquiring two complementary businesses for EUR 680 million. Management attributes EUR 250 million to verified modality-specific technology and patents, EUR 145 million to specialist teams and know-how, EUR 105 million to shared manufacturing, test and control capabilities, EUR 85 million to customer and public-programme access, EUR 55 million to software and orchestration, and EUR 40 million to other net assets and strategic options. It proposes EUR 380 million at closing, EUR 145 million linked to independently defined technical milestones, EUR 85 million in retention instruments and EUR 70 million released against customer, procurement and integration evidence. Every amount is a management assumption created solely to demonstrate the framework; it is not an observed transaction term, valuation, forecast or market benchmark.

The central conclusion is that consolidation earns a scale premium only when shared inputs reduce capital intensity without forcing unlike technical programmes into an unsupported common roadmap. A buyer should preserve distinct modality paths where their failure drivers, development evidence and

customer uses remain meaningfully independent. Price, capital allocation and integration authority should follow reproduced technical evidence, transferable rights, realised shared-input savings and explicit decisions about which options the combined group intends to preserve.

JEL Classification: G34, L22, L86, O32, O33, O38

Keywords: quantum computing, European mergers and acquisitions, superconducting qubits, trapped ions, neutral atoms, photonic quantum computing, scale economics, modality diversification, valuation, technology diligence

Introduction

Europe's quantum ecosystem combines scientific depth, specialist hardware companies, national programmes and shared public infrastructure. The European Commission's 2025 strategy seeks leadership across research, infrastructure, industrial adoption, space and dual-use activity, while EuroHPC is deploying systems based on superconducting, trapped-ion, photonic and neutral-atom approaches. The EPO and OECD describe a globally distributed ecosystem with rapid patent growth and a European scale-up financing challenge. These conditions create a strong rationale for combination and a material risk of premature technical concentration.

The practical decision is whether a proposed merger changes the combined group's probability of reaching useful computation and monetising it at lower total capital cost. That probability depends on the interaction of modality, engineering system, error correction, manufacturing, software, customer access, public procurement, talent, capital and regulatory permissions. A combination can create shared scale. It can also preserve duplicated fixed costs, weaken technical accountability or remove an independent innovation path before evidence has established a winner.

This paper treats scale economics and modality diversification as distinct value pools that must be reconciled. It does not rank one quantum architecture as universally superior. It provides a diligence and structuring method for boards, corporate-development teams, investors and technical advisers evaluating European quantum-hardware transactions.

1 Define the consolidation decision

The board should state the constraint the transaction is intended to remove. A buyer may need higher-fidelity operations, a manufacturable control architecture, access to shared fabrication or test infrastructure, an error-correction capability, a specialised team, a public-procurement position, a customer application portfolio or a credible path into another European market. Each objective requires different evidence and produces a different integration plan.

The decision statement should identify the expected capability after closing and the counterfactual. Management should compare acquisition with internal development, partnership, minority investment, licensing, cloud distribution and targeted hiring. The comparison should include time, capital, execution risk, exclusivity and reversibility. An acquisition can accelerate a roadmap, yet it can also lock the buyer into an architecture before technical uncertainty has resolved.

Market growth projections provide limited support for transaction logic. The decision should rest on a measurable change in capability, capital intensity, customer access or strategic position. The transaction case should specify the evidence that would disprove the thesis before signing and the milestones that will test it after closing.

2 Separate scale value from diversification value

Scale value arises when the combined group can share a scarce input or remove a genuine duplication. It can include fabrication, cleanroom access, cryogenics, vacuum systems, photonic packaging, lasers,

control electronics, calibration, test protocols, software orchestration, customer support, procurement eligibility and corporate infrastructure. A saving is valuable only when the shared resource is technically compatible, available at the required time and capable of supporting both roadmaps without creating a new bottleneck.

Diversification value arises when distinct modalities preserve independent technical or commercial outcomes. Superconducting, trapped-ion, neutral-atom and photonic systems can differ in their error mechanisms, control requirements, supply chains, development evidence and workload fit. A portfolio can reduce dependence on one technical path. It can also consume capital across several programmes without creating a coherent route to revenue.

The two value pools interact. Shared infrastructure can make multiple modality paths affordable. Independent roadmaps can create evidence that improves capital allocation. The buyer should model them separately so that an attractive scale narrative does not conceal a loss of optionality, and a broad portfolio narrative does not conceal duplicated fixed costs.

3 Compare modalities through transaction requirements

Superconducting systems use fabricated electrical circuits at cryogenic temperatures and can support fast gate operations and semiconductor-style process learning. They can require complex cryogenic, packaging, calibration and interconnect systems. Trapped-ion systems use atomic ions controlled through electromagnetic and optical techniques, often with high-fidelity operations and flexible connectivity, while facing engineering questions around speed, optical control and scale.

Neutral-atom systems arrange atoms with lasers and can offer large, reconfigurable arrays and application-specific analogue operation. Their path to universal fault-tolerant computation depends on control, gate, error-correction and continuous-operation progress. Photonic approaches use light and integrated optical components, with potential manufacturing and networking advantages alongside demanding source, detector, loss, switching and system-integration requirements.

The transaction comparison should connect each modality to the target's actual product and evidence. Public roadmaps and demonstrations describe direction; they do not guarantee reproducibility, scale, cost or commercial timing. The buyer should compare the acquired system against the buyer's intended workloads, manufacturing base, cloud model and capital plan.

4 Build a capability map rather than a qubit league table

A qubit count can describe system size without describing useful performance. The buyer should map physical qubits, logical qubits, gate fidelity, connectivity, circuit depth, error-detection and correction, uptime, calibration burden, job throughput, latency, software compatibility and workload results. Each measure should state test conditions, date, version and independent verification.

The map should distinguish scientific demonstration, engineering prototype, available product and contracted service. A result obtained on a selected device under laboratory conditions may be strategically important. Its transaction value depends on whether the target can reproduce it across devices, maintain it over time and expose it through an operable service.

Cross-modality comparison requires caution because native operations, compilation, analogue versus gate models and performance metrics differ. The buyer should use workload-level tests and resource estimates where possible. A conclusion should explain the trade-off rather than compress unlike systems into a single score.

5 Test the path to fault tolerance

Fault tolerance is a programme of architecture, codes, logical operations, decoding, control, fabrication and system engineering. The target should show how physical performance converts into logical capability, which error model applies, what overhead is expected and which milestones have been demonstrated. The buyer should examine the assumptions behind resource estimates and the sensitivity to fabrication yield, loss, crosstalk, control error and decoder performance.

Company roadmaps can support diligence when reconciled with published results, internal test data and engineering plans. Google's Willow announcement emphasised below-threshold error correction on increasing surface-code arrays. IBM's roadmap describes fault-tolerant modules and a longer-term system path. QuEra's roadmap emphasises neutral-atom error-correction demonstrations and continuous operation. Those statements concern different architectures and milestones.

The transaction model should value achieved evidence separately from future milestones. A large portion of modality value may depend on a fault-tolerance claim that remains unproven at the required scale. Contingent consideration can align payment with independently defined demonstrations.

6 Diligence the full hardware stack

The target's moat may sit outside the qubit device. Control electronics, lasers, cryogenics, vacuum systems, packaging, photonics, calibration software, firmware, compilers, test methods and manufacturing recipes can determine performance and cost. The diligence team should identify each critical component, its owner, supplier, replacement time and qualification status.

The buyer should request a system bill of materials and dependency graph. It should identify single-source items, export-controlled components, custom tooling, university licences, foundry agreements and long-lead equipment. Supply agreements should be reviewed for change-of-control rights, volume commitments, price resets, exclusivity and access to failure analysis.

Capital expenditure should be linked to roadmap milestones. A target may need a new fabrication line, cleanroom, cryogenic facility or optical assembly capability before it can deliver the forecast system. The purchase price and integration budget should include that requirement rather than treating it as ordinary post-close growth investment.

7 Verify reproducibility and manufacturing evidence

The buyer should distinguish one high-performing device from a repeatable process. Evidence can include yield, variation, calibration time, failure modes, component life, rework, acceptance testing and performance distribution across systems. The diligence sample should cover multiple devices and production periods where available.

Manufacturing plans should identify which steps are internal, outsourced or shared with research institutions. Intellectual property may protect device design while manufacturing know-how remains concentrated in a small team. The buyer should assess whether process records, tooling, supplier relationships and quality systems can survive staff turnover or a site disruption.

Reproducibility can be made a closing or payment condition. An independent team can build or qualify a device using controlled documentation. The test should protect sensitive technology while demonstrating that the acquired capability is organisational rather than personal.

8 Diligence intellectual property by dependency

Patent counts do not show freedom to operate, enforceability or operational importance. The buyer should map patents, applications, trade secrets, copyrights, licences and know-how to the product architecture and

roadmap. It should identify inventors, assignees, prosecution status, geographic scope, government support, university rights and encumbrances.

The map should show which claims protect the current system and which address future architectures. It should also identify design-around risk and blocking rights held by others. Where the moat depends on trade secrets, the buyer should examine access controls, employee agreements, laboratory records and the extent to which knowledge is documented.

Government-funded and university-originated work may carry licence, reporting, march-in or data-rights considerations depending on the instrument. Qualified counsel should confirm the applicable rights. The transaction should not value an asset as exclusive until ownership and third-party rights are clear.

9 Assess talent as a technical system

Quantum hardware companies can depend on a small number of physicists, device engineers, control specialists and application leaders. The buyer should identify who owns each critical decision, relationship and undocumented method. An organisation chart should be supplemented by a capability and succession map.

Retention design should reflect the work required after closing. Founders may be essential for architecture, but senior engineers, technicians, programme managers and customer scientists can carry equally important knowledge. Retention instruments should use service, transfer and milestone conditions that are achievable and consistent with employment law.

The buyer should evaluate cultural and scientific governance. A large corporate process can improve quality and scale while slowing experimentation. Integration should preserve protected research paths with accountable milestones, peer review and access to shared engineering resources.

10 Define customer access precisely

Customer access can mean a signed contract, cloud listing, reservation, funded research award, pilot, application partnership, reseller arrangement or informal relationship. Each category has different economics and transferability. The buyer should classify the portfolio and avoid treating all named counterparties as revenue customers.

For each material relationship, diligence should cover legal counterparty, product, term, committed and optional value, cancellation, acceptance, pricing, renewal, data rights, intellectual property, exclusivity, security, change of control and required personnel. Usage data should show jobs, reservations, support demand and movement from experimentation toward recurring workloads.

Customer access is valuable when it shortens the buyer's path to paid, repeatable use. A relationship that depends on the target's independent status, founder or modality may weaken after acquisition. The buyer should validate transfer through contract language and customer conversations conducted under an approved process.

11 Separate cloud distribution from customer ownership

Cloud platforms broaden access and reduce the need for customers to procure each provider directly. Amazon Braket documents access to trapped-ion, superconducting and neutral-atom systems, with task, shot and reservation economics. Azure Quantum has also provided access to multiple hardware providers. These channels can create discoverability, workflow integration and billing infrastructure.

A listing does not by itself create a defensible customer asset. The platform may control the billing relationship, usage data, placement and commercial terms. Customers can compare or switch providers.

The target's value depends on contractual rights, differentiated performance, support relationships and the ability to convert platform usage into durable demand.

The buyer should map who owns customer identity, workload metadata, application code, results and support records. It should test whether the acquisition creates a conflict with a platform or other hardware participants. Channel continuity and equal-treatment provisions can matter to valuation.

12 Evaluate European public infrastructure and procurement access

European hardware companies can depend on national research programmes, EuroHPC procurement, shared laboratories, university facilities and sovereign customers. EuroHPC's programme deliberately spans superconducting, trapped-ion, photonic and neutral-atom systems and integrates quantum processors with high-performance computing. A target may hold a supply contract, research award, subcontract, framework position, facility-access right or consortium role. Each instrument creates distinct rights and obligations.

The contract schedule should state the procuring entity, instrument, funding status, deliverables, acceptance tests, intellectual-property and data provisions, eligibility conditions and change-of-control requirements. Participation in a public programme can validate technical relevance without establishing recurring commercial revenue. The buyer should distinguish paid delivery, funded development, research access and announced collaboration.

Eligibility can depend on place of establishment, personnel, facilities, cybersecurity, ownership, supply-chain resilience and continuing European capability. The buyer should confirm whether the combined entity can continue performance, access sites and protect sensitive information. Revenue and strategic-access value should reflect termination, budget, milestone and reprocurement risks.

13 Map public-funding, data and intellectual-property rights

Publicly funded work can create value and restrictions simultaneously. Technical data, software, reports, interfaces, patents and test results may be subject to grant terms, consortium agreements, procurement clauses, university rights or negotiated licences. The target may own foreground intellectual property while another participant or authority holds access, use or dissemination rights.

The diligence team should trace each material capability to its funding source and executed instrument. It should examine background rights, foreground ownership, access rights, publication obligations, exploitation commitments, location conditions, reporting, repositories, subcontractor flow-downs and change-of-control provisions. Inconsistent records can weaken the assumed exclusivity or transferability of an asset.

The buyer should identify rights needed to reproduce, improve and commercialise the technology. A public customer's or consortium partner's rights may facilitate alternative suppliers or constrain exclusivity. The resulting asset may remain valuable, with a different durability, pricing and integration path from wholly proprietary technology.

14 Analyse revenue quality and concentration

Quantum revenue can include hardware sales, cloud usage, reservations, consulting, development contracts, grants and milestone awards. The buyer should separate each stream by margin, cash conversion, recurrence, cancellation and technical dependency. Reported growth can be driven by a small number of awards or acquisitions.

IonQ's 2025 annual filing describes customer concentration, long sales cycles and government-contract risks. It also records significant continuing losses and acquisition activity. Those disclosures illustrate the need to value revenue with its cost and risk rather than applying a mature software multiple.

The buyer should build customer cohorts and contract waterfalls. It should identify how much revenue depends on one agency, platform, research partner or application team. Concentration can be acceptable when the relationship creates technical learning and renewal evidence; it should still be reflected in scenario analysis and liquidity planning.

15 Test application evidence and willingness to pay

The transaction thesis should name the workloads that the combined system is expected to serve. Chemistry, materials, optimisation, machine learning and security are broad categories. The buyer should identify the problem instance, classical baseline, quantum resource requirement, accuracy, total workflow cost and decision value.

Scientific advantage, computational advantage and commercial value are separate tests. A benchmark can show performance beyond a classical method under defined conditions without establishing a paid workflow. An application pilot can show customer interest without establishing scalability or renewal.

Customer diligence should ask what decision changed, what classical method was displaced or complemented, which budget funded the work and what evidence would support expansion. Willingness to pay should be based on contracts and observed behaviour where available. Future application value should remain a scenario until supported.

16 Build the European regulatory perimeter

European quantum-hardware transactions can involve EU and national merger control, foreign-investment screening, export control, sanctions, public-funding conditions, government contracting, data security and national-security review. The perimeter depends on the parties, ownership chain, technology, customers, locations, public support and information access. Qualified counsel should confirm the current requirements for the specific transaction.

Technology classification affects diligence access, integration teams, cross-border collaboration, cloud environments and future sales. The transaction timetable should include classification and licensing work. Foreign and intra-European buyers should map national screening regimes and the EU cooperation framework against the ownership and operating structure. The public final order concerning IonQ's acquisition of Oxford Ionics shows that national-security review can impose continuing requirements concerning UK-based hardware, science, engineering, infrastructure, personnel, assets and manufacturing.

The structure should protect sensitive capability while allowing the combined organisation to operate. Potential mitigations should be converted into facility, governance, access, capital-expenditure and reporting costs before the board approves value.

17 Evaluate innovation competition and input foreclosure

The European Commission's draft 2026 Merger Guidelines expressly address innovation capabilities, innovation spaces, research and development projects, dynamic effects and efficiencies. The Commission's review work includes a study covering quantum computing. For a young industry with uncertain technical trajectories, direct product overlap can be a narrow measure of competitive significance.

The buyer should map competing research paths, critical inputs, suppliers, platforms, public programmes and potential customers. It should identify whether the combined firm could close an independent technical path, restrict access to scarce fabrication or control technology, obtain rivals' competitively sensitive information, or influence a benchmark, cloud channel or procurement route. Patent citation, engineering-team overlap, R&D expenditure, technical dependency and innovation-diversion evidence can inform the assessment when interpreted with scientific context.

Efficiencies require evidence of merger specificity, verifiability and timing. Shared facilities, procurement, software and sales can support the case when compatibility and implementation are demonstrated. Interoperability, information barriers, non-discrimination, supply commitments or preservation of an independent roadmap may address specific concerns. The board should model the cost of each remedy and the value of the innovation option it preserves.

18 Design technical diligence around falsifiable tests

Technical diligence should begin with management's most consequential claims. Each claim should have a test, dataset, version, owner, acceptance threshold and failure implication. Examples include a reproducible fidelity level, logical-error trend, calibration time, job throughput, manufacturing yield or workload result.

The buyer should use independent experts who can evaluate the modality without disclosing restricted information improperly. Clean-room or staged access may be necessary. The diligence report should state what was observed, what was reproduced, what was reviewed only as documentation and what could not be verified.

Claims that cannot be tested before signing can move into transaction mechanics. Holdbacks, milestones, access rights and termination provisions can allocate the uncertainty. A generic warranty that all technology works as intended provides limited protection against roadmap risk.

19 Construct a modality-adjusted valuation

Valuation should separate achieved assets from roadmap options. Achieved value can include functioning systems, patents, software, contracts, qualified facilities and reproducible know-how. Option value can include future fault-tolerance milestones, manufacturing scale, application breakthroughs and new markets. The discount rate or probability should reflect technical and commercial dependencies.

The model can use cost, income and market evidence selectively. Replacement cost may support specialised facilities and documented development, although it does not measure the probability of success. Income analysis can support contracts and customer relationships when cash flows are identifiable. Market transactions require careful normalisation because consideration, stage, modality and strategic context differ.

The board should see a value bridge by capability. A single enterprise value can conceal whether management is paying for technology, talent, channel, contracts, strategic defence or market signalling. Each component should have evidence and a post-close owner.

20 Use milestone-based consideration

Quantum roadmaps create a strong case for contingent consideration when milestones are objective, material and controllable. Technical milestones can include independently reproduced performance, a logical-qubit demonstration, manufacturing yield, continuous operation, system delivery or acceptance. Commercial milestones can include funded awards, customer conversion, renewals or gross-margin thresholds.

The agreement should define the test environment, responsible evaluator, permitted changes, data access, timing, dispute process and treatment after integration. A milestone should not depend entirely on the buyer's discretionary resource allocation. Sellers should have visibility into the work needed to achieve it.

Consideration can combine closing payment, milestone shares, retention instruments and customer-conversion payments. The allocation should distinguish purchase price from compensation and consider accounting and tax consequences. Qualified advisers should confirm the treatment.

21 Protect the roadmap through integration governance

The combined company needs one accountable roadmap. Modality teams may retain distinct research programmes, but shared capital, customers and engineering dependencies require explicit governance. The integration plan should identify which architecture remains primary, which capabilities are experimental and which decisions require board review.

A technical integration council can reconcile hardware, control, software, error correction, manufacturing and application priorities. It should own interfaces, resource conflicts and milestone evidence. Commercial teams should not promise capabilities outside the approved roadmap.

Integration should preserve useful scientific independence while removing duplicated corporate functions deliberately. Early consolidation of laboratories, toolchains or supplier relationships can destroy evidence and slow development. Sequencing should follow technical dependencies.

22 Retain customers during the change of control

The buyer should communicate the combined product, support model and data treatment before uncertainty drives customers to alternatives. Material customers may require consent, security review or revised ordering arrangements. Government counterparties may require notification or novation depending on the instrument.

The retention plan should identify customer owner, workload, contract status, technical dependency, change-of-control requirement, next decision and risk. It should protect continuity of cloud access, reservations, support and application teams. Pricing changes should follow evidence of improved capability rather than the announcement alone.

Customer conversion payments can align deal value with retained and expanded business. The metric should use collected or contractually committed value, defined margin and a clear attribution period. Pilots and non-binding collaborations should not receive the same treatment as recurring paid workloads.

23 Govern security and controlled information

Quantum companies can hold controlled technology, government information, customer data, source code, fabrication records and sensitive research. The integration perimeter should classify repositories, identities, laboratories, devices and collaboration tools before broad access is granted.

The buyer should preserve least privilege, export-control restrictions, contractual access limits and incident evidence. Employees and contractors should be mapped by nationality, location, role and authorisation where legally relevant. Sensitive diligence material should not migrate automatically into ordinary integration systems.

The Day One plan should define security authority, incident escalation, key custody, logging and continuity. A transaction can create risk if two strong control environments are connected without a common design. Security integration should follow a documented architecture and regulatory advice.

24 Build the capital and liquidity plan

Purchase price is one part of the capital requirement. The buyer may need to fund facilities, equipment, foundry commitments, component inventory, research programmes, retention, customer support and operating losses. The integrated model should show liquidity under technical delay and customer-conversion scenarios.

Equity can absorb roadmap risk. Debt may suit predictable assets or contracted cash flows when covenants recognise development volatility. Government awards and customer prepayments can support

milestones, subject to restrictions and performance obligations. The financing mix should not force a premature technical claim to satisfy a near-term covenant.

The board should approve an acquisition reserve for technical and commercial remediation. It should identify conditions that trigger capital reallocation, partnership or programme closure. Strategic importance does not remove the need for portfolio discipline.

25 Define the first 100 days

The first 100 days should protect evidence, people, customers and roadmap accountability. Day One priorities include security, permissions, payroll, customer continuity, laboratory safety, supplier access and decision rights. The integration team should freeze destructive system changes until baselines are captured.

By Day 30, the company should reconcile the capability map, contracts, intellectual property, controlled information and capital plan. By Day 60, it should approve the combined roadmap, customer ownership and supplier actions. By Day 100, it should publish an internal milestone baseline with accountable owners and board reporting.

The plan should include explicit non-actions. Facilities, code repositories, brands and research programmes may remain separate until evidence supports consolidation. Delay can be a controlled decision when it preserves technical value.

26 Monitor value through a deal dashboard

The board dashboard should connect technical, commercial and financial evidence. Measures can include independently verified performance, system availability, job throughput, manufacturing yield, roadmap spend, critical retention, contract value, customer conversion, gross margin, government eligibility and integration risk.

Each measure should state baseline, target, owner, source and decision threshold. Metrics should remain comparable across periods and system versions. A technical improvement that increases cost or reduces availability should be visible as a trade-off.

The dashboard should separate observed results from management forecasts. It should also show milestone consideration and liquidity exposure. The purpose is to support capital allocation and intervention rather than to present a favourable narrative.

27 Prepare downside and exit paths

The buyer should plan for technical delay, modality reprioritisation, customer loss, regulatory restrictions and key-person departure. The downside plan can include licence structures, asset sales, team carve-outs, partnerships, research discontinuation and preservation of transferable intellectual property.

Transaction documents should secure access to records, source, tooling, suppliers and personnel needed to maintain acquired assets. Contingent consideration should adjust when milestones fail for defined reasons. Retention packages should avoid trapping capital in a programme that the board has rationally discontinued.

Exit value depends on clean ownership and separability. The integration design should record which assets and contracts belong to each programme. Excessive technical entanglement can make a future sale or partnership difficult.

28 Set the board decision agenda

The board should ask whether the deal removes a defined constraint, whether the target's capability has been reproduced, whether proposed shared inputs are technically compatible, whether independent failure paths remain valuable, whether regulatory paths are viable and whether the combined roadmap can be funded. It should understand the portion of value attributable to achieved evidence, realised scale and future modality options.

Approval conditions should include technical tests, intellectual-property confirmation, material contract consents, regulatory analysis, retention, security controls and a funded integration plan. The decision record should identify unresolved matters and the mechanism that prices or controls each one.

The final question is accountability. One executive should own shared infrastructure, each retained modality should have a named technical owner, one executive should own customer conversion and one board process should reconcile capital with evidence. The governance system should state which choices remain independent, which resources are shared and which evidence triggers concentration or withdrawal.

Conclusion

A European quantum-hardware merger should be valued as a system of evidenced capabilities and shared inputs. Scale matters when it reduces capital intensity, improves reproducibility or accelerates customer delivery. Diversification matters when independent modalities preserve materially different technical, supply-chain or workload outcomes.

The transaction should separate those value pools, test their dependencies and connect consideration to technical, commercial and integration milestones. Technical diligence should be falsifiable. Scale diligence should identify the exact resource that can be shared and the cost of sharing it. Regulatory diligence should shape information access, structure and timetable. Integration should preserve scientific value while establishing explicit decision rights and one evidence-based capital-allocation process.

Boards can then make a disciplined choice among same-modality consolidation, adjacent-capability acquisition, cross-modality portfolio combination, partnership and internal development. The objective is a combined company with a higher probability of technical and commercial success at a sustainable capital cost, supported by evidence that can be reviewed after announcement and closing.

Appendix A Scale-economics test

The scale test asks whether the target changes the buyer's unit cost, capital requirement, reproducibility, manufacturability, control architecture, customer reach or time to an independently verified milestone. Each claimed saving should identify the shared input, technical compatibility, implementation cost, timing, capacity constraint and responsible team.

The test should compare the target with internal build, outsourcing, partnership and shared-infrastructure alternatives. It should state which assets are transferable and which depend on individuals, suppliers, universities or government permissions. A saving that depends on unverified compatibility or future utilisation should remain contingent value.

The test should be repeated after material changes in roadmap, regulation, supply chain or technical evidence.

Appendix B Modality-diversification test

The diversification test asks whether the target preserves a genuinely independent technical or commercial path. It should identify distinct physical constraints, error mechanisms, supply chains, technical teams,

customer workloads and milestone evidence. A second brand using the same critical inputs and failing under the same conditions provides limited diversification.

Each path should be classified as an evidenced programme, funded development option, exploratory research path or unsupported narrative. Value should reflect remaining capital, probability, correlation with the buyer's existing roadmap, time to decisive evidence and separability.

The test should use reproduced technical results and documented resource dependencies. Future performance should remain a scenario until supported by defined evidence.

Appendix C Quantum M&A data room

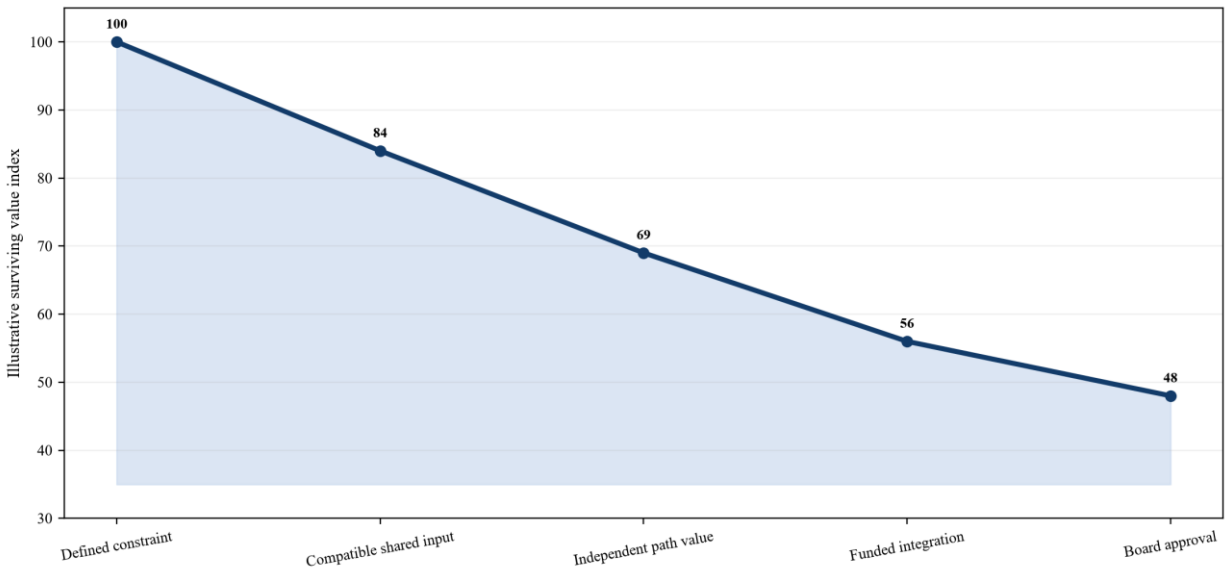
The data room can contain architecture, performance evidence, test protocols, device history, error-correction plans, manufacturing records, bills of materials, supplier agreements, software repositories, patent schedules, invention records, university and government rights, employee agreements, customer contracts, cloud arrangements, security documentation and financial models.

Restricted technical material should use a controlled review process. The diligence report should record information that could not be reviewed and the resulting decision limitation. Missing evidence should become a condition, holdback or milestone.

The final data room should support integration and future financing. Records required to reproduce claims, operate systems and evidence rights should move into controlled repositories with named owners.

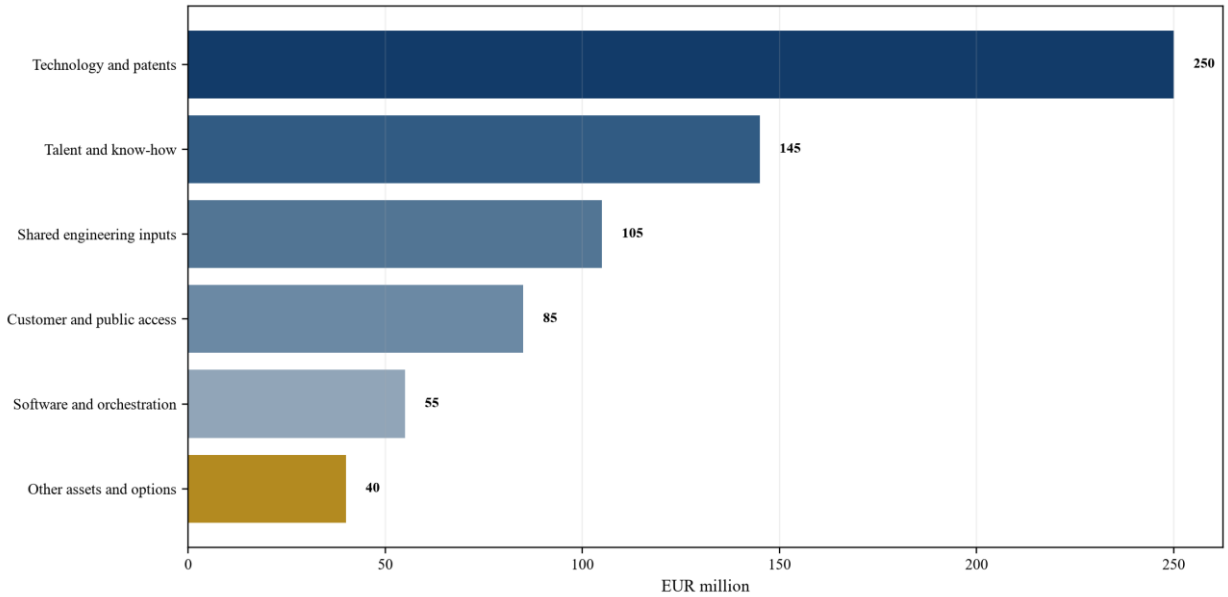
Appendix D Decision figures and tables

Figure 1. Scale-versus-diversification decision path



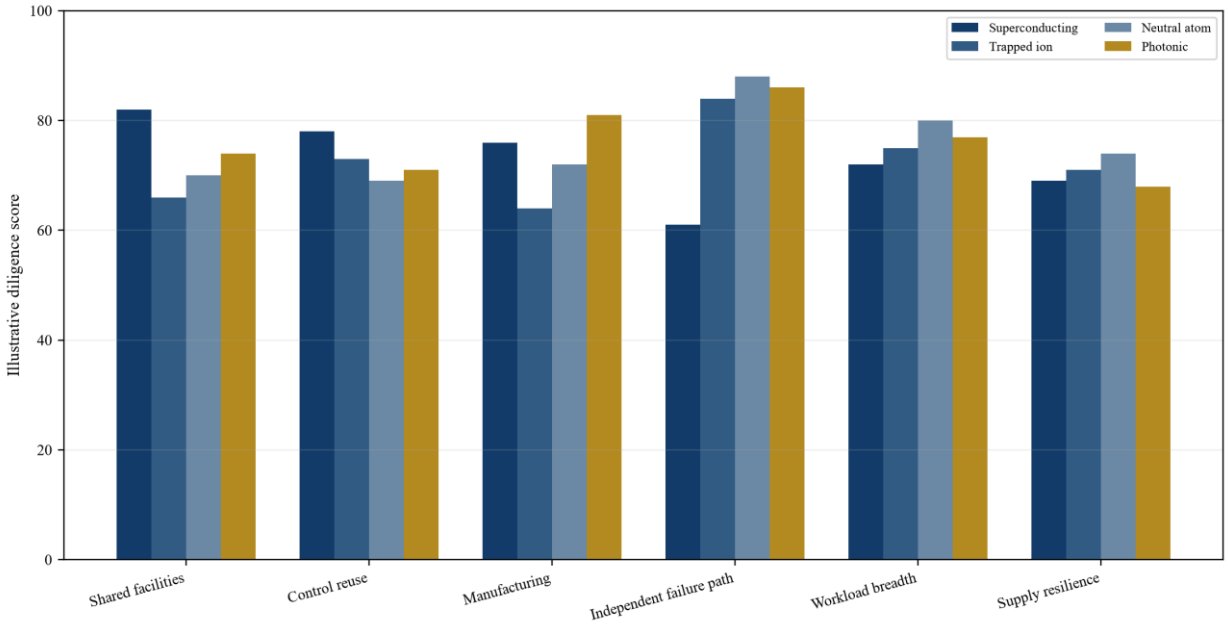
Proposed sequence for separating shared-input value, modality options and integration value.

Figure 2. Hypothetical European quantum-merger value allocation



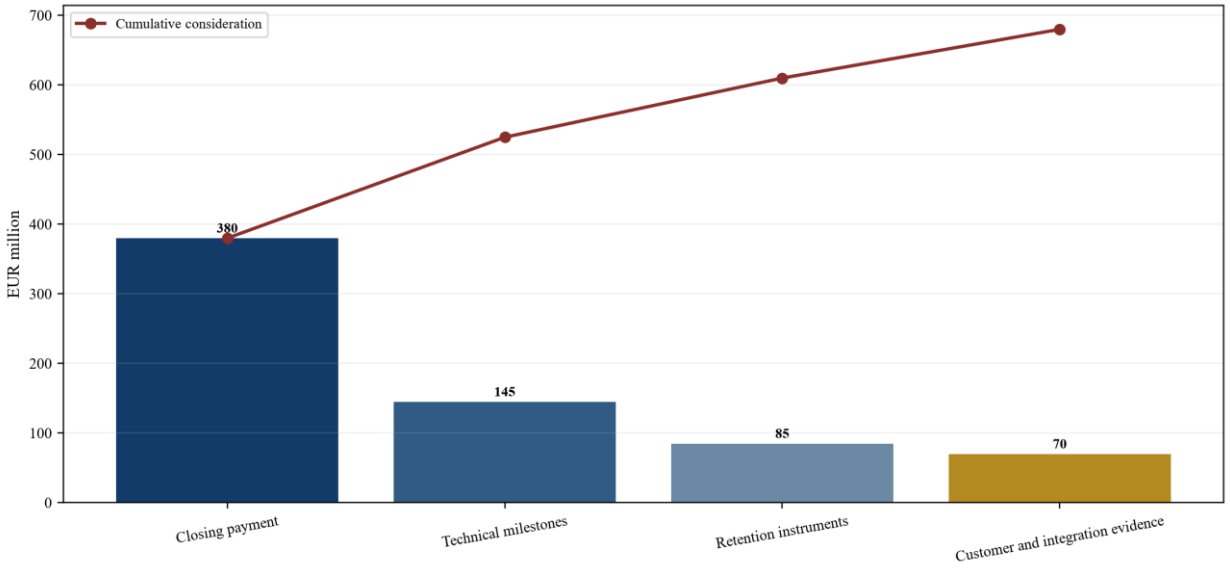
Wholly hypothetical management assumptions; EUR million.

Figure 3. Illustrative scale compatibility and diversification profile



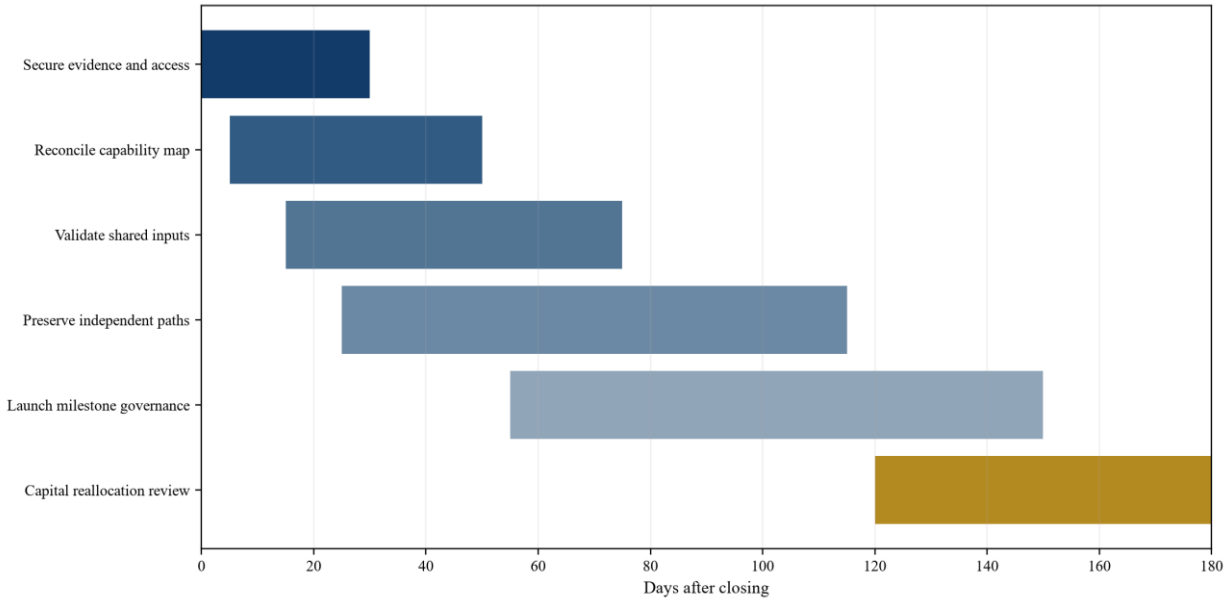
Proposed scoring framework; scores are management assumptions, not comparative technical-performance claims.

Figure 4. Hypothetical evidence-based consideration release



Wholly hypothetical transaction structure; EUR million.

Figure 5. Proposed 180-day integration and option-preservation sequence



Sequencing should preserve technical evidence, independent modality paths and customer continuity.

Table 1. Modality diligence matrix

Area	Superconducting	Trapped ion	Neutral atom	Photonic
Core engineering	Cryogenics, fabrication, packaging and calibration	Traps, lasers, optics and control	Atom arrays, lasers, control and continuous operation	Sources, detectors, loss, switching and integration
Scale question	Yield, wiring, interconnect and error correction	Optical control, speed, modularity and manufacture	Gate quality, universal operation and correction	Component loss, fusion, feed-forward and manufacture
Deal evidence	Multi-device performance and process control	Reproducible fidelity and scalable control	Repeated arrays, gates and logical evidence	Manufacturable components and end-to-end loss budget

Area	Superconducting	Trapped ion	Neutral atom	Photonic
Integration risk	Facility and stack duplication	Specialist-team and optical-system dependency	Roadmap and application-model transition	Supply chain and system-assembly dependency

Proposed transaction questions; no modality is universally preferred.

Table 2. Consolidation-thesis evidence

Thesis	Required evidence	Principal dependency	Transaction treatment
Same-modality scale	Reproduced performance and compatible manufacturing plan	Yield, facilities, suppliers and technical team	Milestone consideration and synergy holdback
Adjacent-capability acquisition	Demonstrated dependency and integration test	Interface, rights and accountable owner	Technical acceptance and retention
Cross-modality portfolio	Independent technical path and funded evidence plan	Capital allocation and separability	Limited upfront option value and staged capital
Public-procurement position	Eligible entity, funded instruments and rights map	Security, programme and personnel conditions	Regulatory condition and contract review

Proposed minimum evidence by thesis.

Table 3. Modality-option quality ladder

Option type	Evidence	Value support	Main risk
Reproduced programme	Independent test, repeatability and funded roadmap	Achieved capability and cash-flow option	Scale and customer conversion
Funded development path	Approved capital, milestones and accountable team	Probability-weighted option value	Delay and capital overrun
Shared-input adjacency	Demonstrated compatibility and capacity	Measurable cost or time benefit	New bottleneck or switching cost
Exploratory research path	Defined hypothesis and decision gate	Capped learning value	No decisive evidence or budget
Narrative option	Presentation or unsigned collaboration	Limited strategic value	Unsupported probability and duration

Proposed classification for valuation and capital allocation.

Table 4. Hypothetical valuation allocation

Value component	Illustrative amount	Evidence gate	Downside treatment
Modality technology and patents	EUR 250 million	Reproduced system tests and rights confirmation	Milestone shares and holdback
Talent and know-how	EUR 145 million	Critical-team retention and transfer plan	Service-based retention instruments
Shared engineering inputs	EUR 105 million	Compatibility, capacity and cost evidence	Synergy holdback and capital gate
Customer and public-programme access	EUR 85 million	Consent, usage and eligibility evidence	Conversion payments and closing condition
Software and orchestration	EUR 55 million	Interface, rights and customer-use evidence	Technical acceptance milestone

Value component	Illustrative amount	Evidence gate	Downside treatment
Other net assets and option value	EUR 40 million	Asset verification and board-approved roadmap	Capped upfront allocation

Wholly hypothetical management assumptions; not observed transaction terms.

Table 5. Regulatory and contract gate map

Gate	Diligence question	Evidence	Decision consequence
Export control	What technology and access are controlled?	Classification, licences and access map	Information perimeter and closing timetable
Foreign investment	Does ownership or access create a national screening issue?	Ownership, technology, location and customer analysis	Filing, mitigation or structure
Merger control	Does the deal remove an innovation path or foreclose a scarce input?	R&D, dependency, input and information map	Remedy risk and thesis adjustment
Public programmes	Do awards, rights and eligibility survive change of control?	Instrument, clauses, consents and eligibility	Consent, mitigation and valuation
Data security	Can systems and repositories be combined lawfully?	Classification, architecture and controls	Staged integration and information barriers

Qualified counsel should confirm the current transaction-specific requirements.

Table 6. First 180-day board dashboard

Measure	Day 10	Day 45	Day 90	Day 180
Technical evidence	Baselines secured	Capability map reconciled	Independent paths approved	Milestone results reviewed
Customers	Continuity owners assigned	Consents and risks mapped	Conversion plan active	Retention evidence reported
People	Critical roles confirmed	Retention executed	Succession gaps funded	Capability transfer measured
Regulation	Access controls preserved	Filing and licence map current	Mitigation actions funded	Compliance dashboard active
Capital	Liquidity protected	Integration budget reconciled	Option budgets approved	Portfolio allocation reviewed

Proposed evidence schedule.

Table 7. Board approval thresholds

Decision area	Green evidence	Amber condition	Red condition
Scale	Compatible shared inputs create timed and measurable savings	Material saving remains testable and priced	Claimed saving requires incompatible systems or unavailable capacity
Diversification	Independent path has reproduced evidence and funded gates	Option has bounded capital and a decisive milestone	Path duplicates failure drivers and lacks a decision gate
Regulation	Viable classification, filing and operating path	Defined approval risk with protected timetable	Required access or ownership is unlikely to be permitted

Decision area	Green evidence	Amber condition	Red condition
Integration	One roadmap, owners and funded sequence	Temporary duplication with decision date	Conflicting architectures and no accountable owner
Economics	Value bridge and downside funding are explicit	Option value is capped and milestone-linked	Price depends on unsupported market projection

Proposed decision framework.

Frequently asked questions

Q: Should a buyer choose a quantum target primarily by qubit count? A: No single qubit count establishes useful performance or transaction value. The buyer should evaluate fidelity, connectivity, logical capability, circuit depth, throughput, uptime, reproducibility, manufacturing, workload fit and the full control stack under defined test conditions.

Q: How should superconducting, trapped-ion, neutral-atom and photonic companies be compared? A: Compare each target against the buyer's intended workloads, fault-tolerance plan, manufacturing base, capital capacity and route to market. Use modality-specific tests and workload evidence. Avoid compressing unlike architectures into one unsupported ranking.

Q: When does consolidation create genuine scale economics? A: Scale value requires a specific shared input, demonstrated technical compatibility, sufficient capacity, a timed implementation plan and a measurable reduction in capital, unit cost or delivery time. A broad corporate-overhead estimate provides limited evidence of hardware scale.

Q: How should technical roadmap risk affect consideration? A: Separate achieved capability from future options. Pay a larger portion of uncertain value through objective technical milestones, retention instruments, customer-conversion payments or holdbacks. Define tests, data access, timing and dispute procedures precisely.

Q: What should a buyer examine in European public programmes? A: Review the executed instrument, funding, acceptance, security, audit, intellectual-property, data-rights, change-of-control, location and eligibility provisions. Confirm whether the combined entity, facilities and required personnel can continue performance.

Q: When does a second modality provide diversification value? A: A second modality provides diversification when it has materially different failure drivers, supply-chain dependencies, technical evidence and workload applications. The option should have a bounded budget, a decisive milestone and a governance path that preserves technical independence.

Q: What is the principal integration risk in a cross-modality merger? A: The combined company can retain several expensive roadmaps while forcing them through shared resources that are not technically compatible. Named owners, protected evidence paths, explicit interfaces and capital decision gates reduce this risk.

Q: What should the board require before approving a European quantum-hardware merger? A: Require a defined constraint, reproduced technical evidence, a shared-input and dependency map, verified intellectual-property rights, an innovation-competition analysis, public-programme continuity, retention, a funded integration plan, milestone consideration and downside liquidity.

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