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COSMIC Quantum Software Taskforce
2025 report

COSMIC 2025 Annual Meeting

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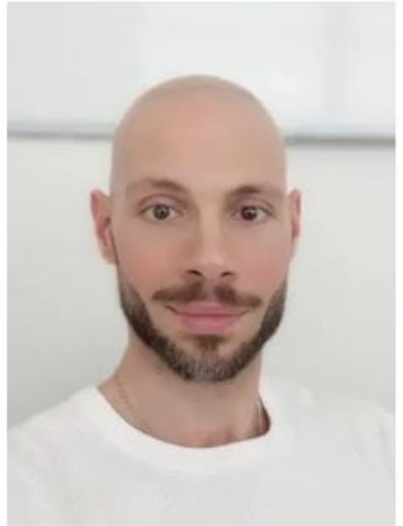

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Initial Action Items

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Quantum Software Sizing using COSMIC with case studies

- ✅ Review circuit-based case study with the COSMIC Group.
- Review Khattab (2022) and Valdes-Souto (2024) approaches with the COSMIC Group.
- Prepare new case studies.
- Consolidate the three sizing approaches.
- Analyze past Quantum student club challenges from a functional requirements perspective.

Systematic Literature Review on Quantum Size Measurement

- Conduct a systematic literature review on size measurement in Quantum Software.
- Analyze Quantum Volume (QV) and other relevant metrics.

Exploration of Measurement components in Quantum as NFR

- Explore error and fidelity concepts within the scope of measurement as non-functional requirements (NFR)

2025 achievements -1

1. Quantum Software Size Measurement Webinar

- The follow-up post-workshop webinar was held on March 26, 2025.
  - To access the presentation slides, click Presentation- Quantum Taskforce Webinar.
  - To access the comprehensive report click Report- COSMIC Quantum Taskforce.
  - To access webinar recording click Recording- Quantum Webinar.

2025 achievements - 2

2. An Investigation of functional size measurement of error correction overhead in quantum software

(submitted to Information and Software Technology Journal)

An Investigation of functional size measurement of error correction overhead in quantum software

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ABSTRACT

Context: As quantum computing progresses toward fault-tolerant implementations, quantum error correction (QEC) has become a dominant concern for quantum hardware and software. The overarching goal of QEC is not only to recover from individual qubit failures, but also to maintain the integrity of an entire quantum computation in the presence of persistent noise. While conventional QEC measurements, such as qubit overhead, code distance, and error thresholds, quantify physical resource costs, they do not capture the software-level functionality introduced by error detection, correction, and fault-tolerant gate protocols.

Objectives: This study investigated the hypothesis that QEC significantly contributes to the functional size of quantum software and demonstrated that these contributions can be systematically measured using the COSMIC Functional Size Measurement (FSM) method.

Methods: A gate-level sizing approach, known as Gates' Occurrences, was applied to quantify functional user requirements (FUR) associated with QEC processes, including logical encoding, syndrome extraction, and recovery operations. A prototype measurement tool, implemented in Qiskit, enables the automated calculation of COSMIC Function Points (CFP) from annotated circuit representations.

Results: Case studies involving Bell state preparation, Grover's search algorithm, and 15-to-1 magic state distillation have revealed that QEC-related functionality can account for 70–85% of the total functional size, even under simplified encoding assumptions.

Conclusion: These results support the hypothesis and underscore the importance of QEC for the functional size of quantum software. These findings provide a reproducible framework for functional sizing in quantum software engineering and offer a foundation for future extensions to other fault-tolerant architectures and abstraction levels.

2025 achievements -3

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3. Quantum Software Size: What do we measure. How and why? A Systematic Literature Review

(will be submitted to IEEE Access)

Quantum Software Size: What Do We Measure, How and Why? A Systematic Literature Review

ABSTRACT The rapid growth in quantum computing has created an urgent need for quantum software systems that require traditional software engineering methodologies to be adapted or redefined. Among these methodological challenges, software size measurement plays a central role in project estimation, quality assurance, and software engineering management. However, currently, there is no consolidated understanding of how it should be applied to quantum software systems. This paper presents the first systematic literature review on quantum software size measurement, synthesizing existing approaches, and identifying key research gaps. An analysis of 16 studies shows that size measures span multiple abstraction levels, with most research focusing on adapting classical metrics, such as Lines of Code (LOC) and functional size, to quantum systems. LOC continues to be used for sizing quantum code, while COSMIC Function Points (ISO 19761) have been extended to capture data movements in quantum components, enabling their application at the requirement, code, and circuit levels. At the specification and architectural design levels, the proposed measures include counts of quantum classes and methods, as well as lines of architectural specifications. At the circuit level, quantum-specific constructs, such as qubits, gates, and measurements, are also incorporated. Additionally, software structure metrics, including cyclomatic complexity and Halstead metrics, measure quantum software at both code and design levels. Research output has grown rapidly since 2024, driven mainly by academic groups with minimal industrial participation. However, most metrics remain conceptual, empirically unvalidated, and not integrated into development life cycles, highlighting the immaturity and fragmentation of current proposals and the need for standardized frameworks.

2025 achievements - 4

4. Functional Size Measurement of Hybrid Classical Quantum Software Systems

(accepted in Global Congress of Emerging Technologies, GCET 2025, Lyon, France)

Functional Size Measurement of Hybrid Classical Quantum Software Systems

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Abstract*—*Accurate sizing of software systems is essential for effective project management and resource allocation. Hybrid classical–quantum software systems consist of a quantum component, which executes quantum algorithms and incorporates error correction mechanisms (overhead)—a critical aspect in the Noisy Intermediate-Scale Quantum (NISQ) era—and a classical component, which controls quantum operations and manages error propagation. This paper explores functional sizing for hybrid classical-quantum software. It highlights the challenges arising from the interaction between the classical and quantum components, particularly with respect to the abstraction layers and granularity levels. A key principle emphasized is that functional sizing should not extend across multiple abstraction layers within a single measurement scope. While quantum software typically operates at a low-level implementation-specific layer, classical software generally functions at a higher level of abstraction. This divergence emphasizes the need to clarify how functional size measurement should be applied using set theory to account for requirements specified at different abstraction layers in hybrid computing environments.

***Index Terms*—Quantum computing, software size measurement, COSMIC.**

I. Introduction

Unlike classical software, which is based on deterministic operations and binary logic, quantum software leverages the principles of quantum mechanics, that is, superposition and entanglement, to enable computations beyond the capabilities of classical machines [1], [2]. This has given rise to hybrid classical–quantum software systems, where classical components manage system control and error propagation, whereas quantum components implement quantum algorithms and error correction schemes [3], [4]. These systems introduce novel challenges compared to conventional software engineering [5].

An important aspect of software engineering is software sizing, which supports key activities such as project planning, resource allocation, and performance optimization. Traditional sizing has evolved from Lines of Code (LOC) to Function Points (FP), such as the COSMIC Functional Size Measurement (FSM) method as defined in ISO 19761 [6]. However, when applied to hybrid classical–quantum software systems, special care should be taken, as they do not account for the distinct operational semantics, abstraction levels, and architectural partitioning introduced by quantum computing components [7].

This study investigates the applicability and limitations of existing software sizing in the context of hybrid classical quantum software systems. It explores the methodological gaps that arise when the classical domain is extended into the quantum domain and proposes an approach taking into account the hybrid architecture. Furthermore, the paper identifies key challenges regarding abstraction and granularity and outlines directions for future research and standardization efforts in this rapidly evolving field [8].

The remainder of this paper is organized as follows. Section II provides an overview of the evolution of software sizing needs, transitioning from classical to hybrid software systems, and introduces the COSMIC Functional Size Measurement method as defined in ISO 19761 [9]. Section III explores the key challenges and open questions in measuring the functional size of hybrid classical quantum software. In Section IV, we present our proposed approach for sizing hybrid software systems in four dimensions. Section V offers a discussion of the broader implications and future standardization efforts. Finally, Section VI concludes the paper by summarizing our

2025 achievements - 5

5. Insights on Quantum Software Functional Size Measurement: Key Concepts, Challenges

(accepted in Global Congress of Emerging Technologies, GCET 2025, Lyon, France)

Insights on Quantum Software Functional Size Measurement: Key Concepts, Challenges and Motivations

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***Abstract*—The rapid evolution of quantum computing has led to growing interest in the development of systematic approaches to assess and manage quantum software. Among these, functional size measurement (FSM) offers a promising pathway for establishing metrics that can support project estimation, benchmarking, and quality assessment. This paper provides an overview of emerging efforts in quantum software functional size measurement with a focus on key concepts, challenges, and motivations. First, we examine the foundational principles of quantum computing in relation to the existing FSM methods, identifying both compatibilities and unique constraints. Building on this, we discuss the challenges that arise when applying FSM to quantum software, including the hardware-coupled nature of functionality, evolving semantics of data and measurement abstractions, gaps in tooling and standardization, and evolving role of FSM across the Noisy Intermediate-Scale Quantum (NISQ) and future fault-tolerant eras. We then outline community-driven initiatives, such as the COSMIC Quantum Software Taskforce and the Fall 2024 Workshop, which highlight the increasing demand for structured measurement practices. By articulating these issues, this paper aims to present initial research efforts for quantum software functional size measurement and stimulate further exploration of measurement approaches that are both theoretically grounded and practically applicable in quantum software engineering.**

***Index Terms*—Quantum software, functional size measurement, COSMIC ISO 19761.**

I. Introduction

As quantum computing transitions from a theoretical exploration to a practical implementation, the need for measurement methods in quantum software development has become important. Although research in quantum software engineering has gained momentum in recent years, it is still in its early stages of development. For instance, software measurement, an essential practice in classical software development, is still underexplored, and studies on the measurement of quantum software are currently limited. To address this gap, some initiatives have emerged, such as the COSMIC Group Task Force [1]. The COSMIC Group has recognized that leveraging COSMIC Function Points in the context of quantum software sizing requires the development of a body of new, highly specialized knowledge. To address this need, the COSMIC Quantum Taskforce has adopted a structured approach. This begins by building a common understanding of the functional characteristics unique to quantum software and how these characteristics differ from those of traditional software domains. The taskforce is also working to identify possible adaptations of the existing COSMIC measurement procedures to suit the requirements of quantum software.

An initial set of quantum-specific measurement procedures has been proposed in the literature [2]–[4]. To validate and refine these procedures, the group conducted field tests using case studies that focused on measuring quantum-specific algorithms. These efforts were supplemented with internal reviews by the COSMIC community to ensure quality and relevance. The eventual outcome will be an initial public version of the quantum sizing guidelines, representing a foundational step toward standardizing functional size measurement in the quantum software domain. These efforts also seek to highlight the unique measurement challenges associated with quantum

Actions planned for 2026

1. Analyze Quantum Volume (QV) and other relevant metrics.
2. Exploration of COSMIC Early Sizing techniques for Quantum Software sizing in different levels of abstractions
3. Exploration of COSMIC NFR Guideline for Quantum NFRs
4. Exploration of set Theory for reporting COSMIC measurement results in different levels of abstractions
5. Case studies to measure the quantum software in 3-levels of abstractions
6. Development of a measurement reporting framework

For more information visit our Website

Quantum Software Sizing

Industry Context

Information technology is evolving rapidly, and when its impact is very significant (as in mission-critical and safety and health-related software systems), the design of software measures and related software measuring instruments, including measurement case studies as reference material, must evolve to stay ahead of software technology. The COSMIC Group has set up a taskforce on Quantum software to address the gaps and weaknesses in the coverage of its set of software sizing measurement Guidelines and case studies.

COSMIC Quantum Software Taskforce approach

The COSMIC Group had identified that a considerable amount of new highly specialized knowledge must be developed to leverage the benefits of using COSMIC Function Points in Quantum Software sizing context. The COSMIC Quantum taskforce approach consists of

- Development of a common understanding of the functional characteristics in quantum software, their uniqueness in comparison to previous domains, and with a focus on the sizing of algorithms for quantum software.
- Identification of alternatives for the tailoring of COSMIC measurement procedures for sizing quantum software requirements.
- A initial design of quantum specific measurement procedures.
- Field tests through the design of quantum specific algorithms measurement case studies.
- Internal COSMIC reviews for validation and improvements.
- An initial public version

Benefits

The availability and international recognition of such standard measurement standards for sizing in Quantum software context is of practical interest to software organizations and their customer bases, for both small and large organizations at an international level.

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To learn more about COSMIC Quantum Software Taskforce please click here.

Quantum Software Sizing Taskforce Activities

- The workshop on Quantum Software Sizing was organized by the COSMIC Quantum Software Taskforce and held on Sept. 30, 2024 during the IWSM-MENSURA 2024 conference (see poster on the right for the list of topics.)

- The follow-up post-workshop webinar was held on March 26, 2025.
  - To access the presentation slides, click Presentation- Quantum Taskforce Webinar.
  - To access the comprehensive report click Report- COSMIC Quantum Taskforce.
  - To access webinar recording click Recording- Quantum Webinar.

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