# Meta-Heuristic Algorithms for the Quantum Circuit Compilation Problem

## Executive Summary

**Authors:** Angelo Oddi[1], Riccardo Rasconi[1], Vieri Giuliano Santucci[1], Marco Baioletti[2], Hamish Beck[3]
**Affiliation:** [1]ISTC-CNR, [2]University of Perugia, [3]ESA ACT

**Date: 23 December 2021**

**ACT research category:** Physics / Artificial Intelligence

**Contacts:**

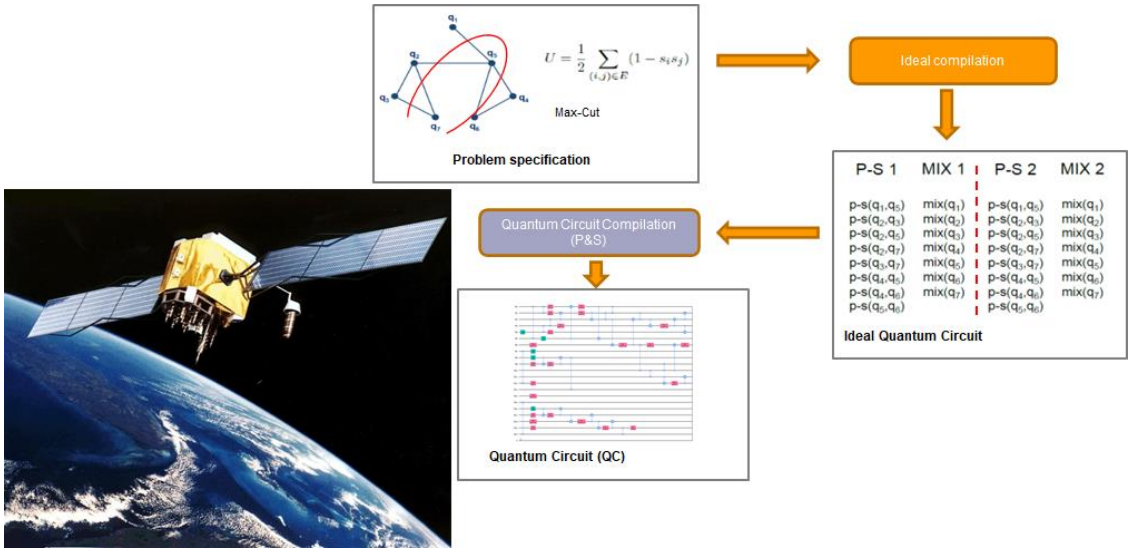
Angelo Oddi
Tel: +39-06-44595-214
Fax: +39-06-44595-243
e-mail: angelo.oddi@istc.cnr.it

Leopold Summerer (Technical Officer)
Tel: +31(0)715654192
Fax: +31(0)715658018
e-mail: act@esa.int

Available on the ACT website
http://www.esa.int/act

**Ariadna ID:** 21/1201
**Ariadna study type:** Standard
**Contract Number**: 4000134995/21/NL/GLC/my

**Picture:**




**Motivation:**
Exploring the use of quantum computing as an accelerator for the resolution of optimization problems in the space domain, and studying the compilation techniques for Noisy Intermediate-Scale Quantum (NISQ) Devices.

**Methodology:**
The aim of the study was to present efficient compilation algorithms for large quantum circuits, paving the way for their execution with future Noisy Intermediate-Scale Quantum (NISQ) Devices, which is a necessary step to demonstrate the superiority over the existing classical algorithms for combinatorial optimization.

We produced a greedy randomized search (GRS) algorithm targeted at optimizing the compilation of Quantum Approximate Optimization Algorithm (QAOA) circuits, and identified two reference problems of interest: (i) the Max-k-Cut problem, and (ii) a prototype space application, I.e., the scheduling of space-ground communications (the Communication Satellite Problem). We empirically tested the validity of our compilation algorithm by producing two benchmark sets related to both previous problems, and solving them by means of Jupyter notebooks.

**Results:**

- A quantum compilation algorithm for **Max-k-Cut** (a generalization of the well-known graph colouring problem);
- A prototype **space application** (scheduling of space-ground communications) solved via a reduction to Max-k-Cut;
- A Python module using **Qiskit** (https://qiskit.org).

**Publications:**
*No publication submitted so far*

**Highlights:**

We reduced the proposed satellite scheduling problem to a variant of the well-known graph colouring problem known as list colouring [Marx 2004], and selected the one-hot coding schema so as to reduce the total number of necessary qubits to be used in the quantum hardware.

We compared our quantum compilation algorithm used on satellite scheduling problem instances with the BasicSwap, StochasticSwap, SabreSwap and LookaheadSwap algorithms currently present in Qiskit, obtaining better results in terms of circuit depth minimization.