A major operational planning problem in the air cargo industry is how to arrange cargo in an aircraft to fly safely and profitably. MemComputing proposes an innovative solution to solve this challenge efficiently

MemComputing Inc.

Aircraft Cargo Loading Optimization Case Study

Aircraft Cargo Loading (ALO)

Air cargo volumes: +3% per year

The air freight sector is particularly well positioned today as a result of capacity discipline and consolidation in container shipping. According to McKinsey, air-freight volumes will nevertheless continue to increase, by an average of **about 3% per year, at least until 2025 and most likely until 2030.**

Optimized cargo operations

Despite this very promising prospect, cargo fleets face some challenges. “A faster growth in belly capacities and modernized freighter fleets will subject general cargo to price pressures of up to 3% a year” according to McKinsey. This will counterbalance the higher transport volumes leading to flat revenues.

Optimization of operations and in particular Aircraft Loading Optimization (ALO) will play a key role in supporting a sustainable growth for the airlines.

Air Cargo Loading (ALO): a key challenge

A major operational planning problem in the air cargo industry is how to arrange cargo in an aircraft to fly safely and profitably. A challenging planning puzzle has to be solved for each flight. ALO requires **optimizing the placement of containers of different sizes and weights in an aircraft subject to limitations** on the maximum weight allowed, the maximum tolerable shear and the center of gravity.

Different stakeholders have various objectives. Ground handling players want to minimize their effort and insure an even workload. Aircraft operations mostly target a minimization of fuel consumption and of so called Unit Load Device (ULD) operations. On their side, Air cargo sales teams mostly aim at maximizing revenue and cargo loads on planes.

Overall, Airlines make the best use of an aircraft’s payload capability to **maximise revenue, optimize fuel burn, lower overall operating costs**.

It is the *Load Master’s* role to accurately plan the load (loadsheet), complying with all operational and safety requirements. In the past this has been accomplished manually but more recent “drag and drop” applications are used but remain of limited use in view of an increased complexity.

Improving Aircraft Loading Optimization A Mathematical & Computing Challenge

Solutions to today's computational limits are provided by more and more sophisticated and high-performing CPUs, GPUs as well as by the insurgence of distributed computing in cloud infrastructures. Nevertheless, the unceasing growth in computing demand is pushing towards completely **new architectures as well as new paradigms**.

This can mean not only "handling more computation" but also making the computation more efficient.

Complex optimization problems are often classified as "NP-hard" or "NP-Complete". "NP" problems are problems which are unsolvable within a reasonable amount of time for large input sizes.

NP-Hard problems refer to a class of problems that grow exponentially in complexity with the addition of each new input variable. These problems are often combinatorial, where **the combination of possible solutions or permutations grows at an increasing rate for each additional input**.

Consider a simple problem with colors where you can have 100% of each color or you can mix them in equal amounts. If you start with a single color, green, then the only color you can make is green. If you add red, you can now have green, red and yellow (green + red). If you add blue, you can now have green, red, blue, yellow (green + red), cyan (green + blue), magenta (red + blue) and white (green + red + blue). Keep going and you can see that the number of possible colors grows exponentially each time you add just one more color.

Solving Logistics and other Problems with MemComputing

The MemCPU™ Coprocessor technology takes a new approach to computation of complex optimization problems, especially those that are combinatorial in nature. It is completely different from any method previously taken. This technology is an extreme turbo-booster for virtually any computer, from the slowest laptop to the fastest supercomputer. This computing increase isn't simply ten or one hundred times faster, it is hundreds, thousands, tens of thousands or more times faster depending on the problem. In effect, the harder and more complex the problem, the greater the boost in performance. MemCPU Coprocessors are designed to handle massive and complex mathematical computations in a fraction of the time using a fraction of the resources of today's best in class solutions.

Today's classical (non-quantum) computers are confined when it comes to solving a class of problems categorized as NP-hard and NP-complete. These problems are identified where the computational time and/or memory resources required explode exponentially while the inputs and constraints simply grow sequentially.

The outstanding performance of our physics-based approach shows advancements in optimization computations. In previous benchmarks MemComputing has shown empirical evidence that a non-combinatorial approach using its MemCPU Coprocessor demonstrated the availability of efficient solutions to NP-hard problems.

MemCPU Coprocessors are designed to integrate with current workflow. The software supports integer linear programming problems (ILP), quadratic unconstrained binary optimization problems (QUBO), polynomial unconstrained binary optimization problems (PUBO), Maximum Satisfiability (Max-SAT) and some Satisfiability problems (SAT), with more methodologies and capabilities being added. The software supports direct data exchange as well as file-based data exchange with Mathematical Programming Systems (.mps) and Conjunctive Normal Form (.cnf).

The Airbus Computing Challenge

In January 2019, Airbus launched a computing challenge to solve a set of problems relevant for the aircraft life cycle, expecting to investigate nontraditional solutions for logistics optimization problems.

The Airbus Quantum Computing Challenge (AQCC) addresses aerospace flight physics problems developed by company experts. It puts forward five distinct flight physics problems with varying degrees of complexity, ranging from a simple mathematical question to a global flight physics problem and it aims to investigate how newly-available computing capabilities can solve the 5 following real-life industrial challenges met by the aerospace industry today

- Aircraft Climb Optimization,
- Computational Fluid Dynamics,
- Quantum Neural Networks for Solving Partial Differential Equations,
- Wingbox Design Optimization,
- Aircraft Loading Optimization.

Airlines try to make the best use of an aircraft's payload capability to maximise revenue, optimize fuel burn and lower overall operating costs. Their scope for optimization is limited by the aircraft's operational envelope, which is determined by each mission's maximum payload capacity, the aircraft's center of gravity and its fuselage shear limits.

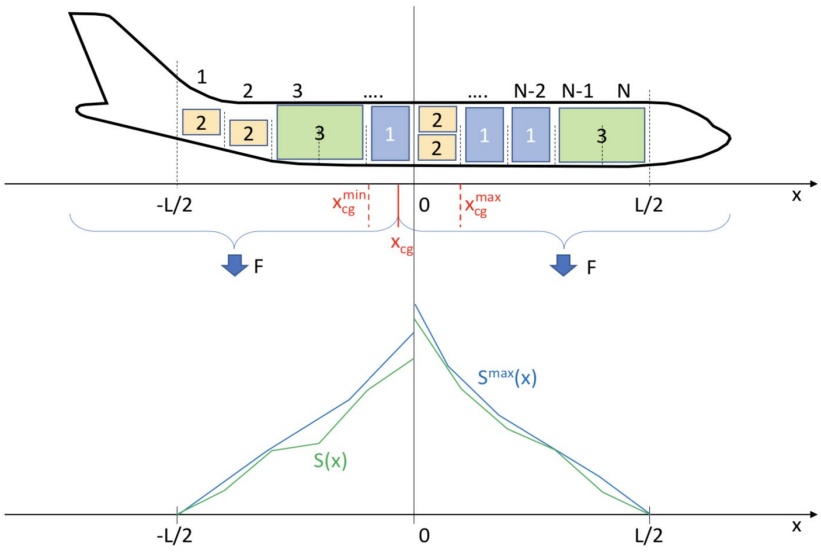
The objective of this challenge is to calculate the optimal aircraft configuration under coupled operational constraints, thus demonstrating how quantum computing can be used for practical problem solving and how it can scale towards more complex issues.

Sketch of the Airbus Aircraft Loading Optimization problem.

The aircraft is to be loaded by selecting a portion of the available payload. The containers can have different shapes.

For this ALO, 3 different shapes are considered numbered from 1 to 3 as in the figure. The maximum weight allowed is limited.

The center of gravity x_{cg} of the system aircraft + containers must remain within the limit $[x^{min},x^{max}]$ and the shear curve $S(x)$ must also be limited to remain under a give shear limit curve $S^{max}(x)$.



MemComputing's approach to Aircraft Loading Optimization

MemComputing employed the software-based MemCPU Coprocessor to tackle the 5th Airbus problem efficiently without a quantum computer.

In order to use the MemCPU Coprocessor for the 5th Airbus problem, a standard Integer Programming (IP) problem has been formulated that includes **all constraints required by Airbus with no exception and no approximation**.

The scaling properties assessed during the project showed ***sub-quadratic scaling*** as a function of the size of the problem measured by the number of nonzero elements of the constraint matrix of the associated IP problem. The scaling properties of the MemCPU Coprocessor allow **efficient solutions of large ALO problems and…**

IT REPRESENTS A SOLUTION READY TO BE DEPLOYED IN THE FIELD TODAY!

MemCPU Coprocessor
An entirely new paradigm

- Computation & Memory Combined in the same circuit with a brand new/patented computer architecture
- Uses classical low power, low heat transistor technology
- Emulated in software, it runs on classical architecture

A successful solution

- The MemComputing technology can dramatically reduce the computing time needed for processing today's most complex logistics problems.
- MemCPU Coprocessors are a viable solution to at least some NP-Hard problems.

Bottom line

MemComputing can solve problems that are currently considered unsolvable because the time required could be years, decades or even eons for current best in class solutions using classical methods!

Transportation, Logistics

MemComputing is working with companies on transportation logistics problems in airline, rail, trucking, busing and shipping.

MemComputing helps solve traffic problems by optimizing the routing for taxis in our largest cities and by managing traffic signal assets for smart cities.

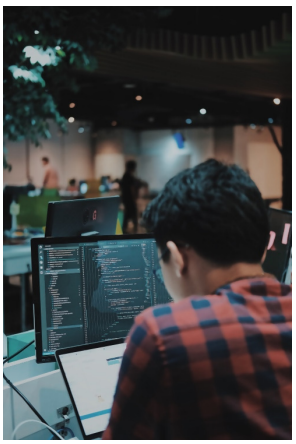
One example within the autonomous vehicle market is that MemComputing can analyze a larger set of inputs from radar data in order to significantly improve the resolution and accuracy.

Offloading more and more of the computations for autonomous vehicle, such as motion control and collision avoidance, to MemComputing also reduces the amount of computer hardware required thus freeing up cargo space

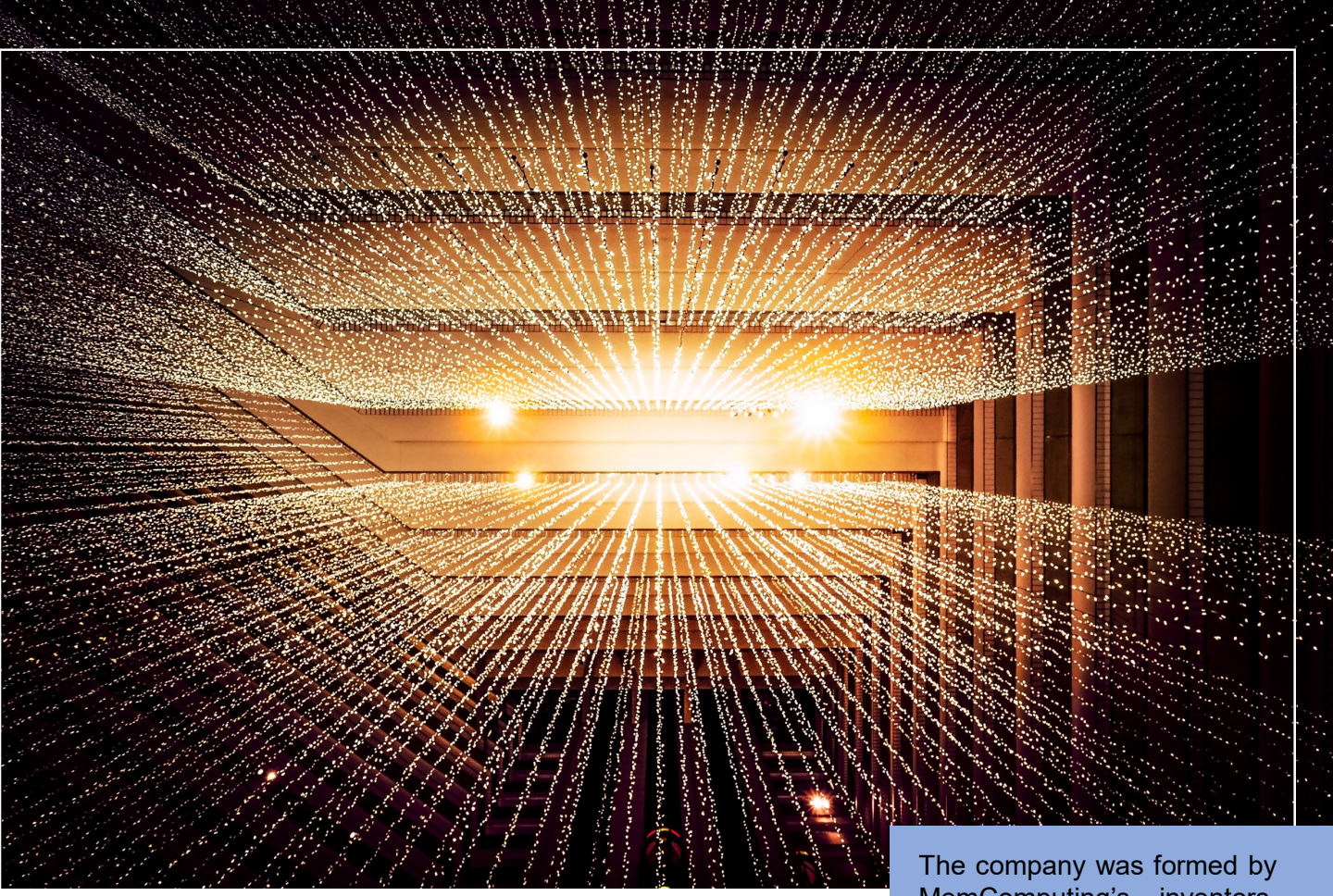
Logistics Beyond Air Freight

Logistics casts a net over far more than air cargo freight. The importance of modernizing logistics with digital automation will impact all facets of management and control of the transportation, mobility and warehousing/storage of goods for satisfying consumer demands. It's fundamental to the supply chain.

As e-commerce continues to explode, and the volume of goods being transported worldwide is booming, business and consumer expectations for faster order delivery will continue to place pressure on the entire transportation logistics and supply chain network. In turn this is putting strains on capacity, infrastructure and the workforce. It's making **logistics problems seem impossible to solve in reasonable amounts of time.** The digitalization of multi-modes of transportation as well as extended services to track the real-time movement of goods into and out of business is an integral factor in the success of any industrial company.



The MemComputing technology solutions will not replace Data Scientists. Companies will still require their scientists to develop the models for the problems that they wish to solve. We believe that early adopter data scientists that take advantage of the MemComputing technology and **integrate a MemCPU Coprocessor into their solutions will bring tremendous value to their organizations**.



ABOUT MEMCOMPUTING, INC.

MemComputing, Inc.'s disruptive coprocessor technology is accelerating the time to find feasible solutions to the most challenging operations research problems in all industries. Using physics principles, this novel software architecture is based on the logic and reasoning functions of the human brain.

MemComputing enables companies to analyze huge amounts of data and make informed decisions quickly, bringing efficiencies to areas of operations research such as Big Data analytics, scheduling of resources, routing of vehicles, network and cellular traffic, genetic assembly and sequencing, portfolio optimization, drug discovery and oil and gas exploration.

MemComputing Inc. has developed disruptive technologies that are changing the face of computing through a SaaS solution that improves the performance of today's most complex and time consuming optimization calculations by 4 orders of magnitude or greater.

The company was formed by MemComputing's inventors, PhD Physicists Massimiliano Di Ventra & Fabio Traversa along with serial entrepreneur, John Beane.

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