ULTRA**RAM in Space**

Quinas Technology Limited

1. Introduction and motivation

The space sector has reached a pivotal moment. Commercialisation has stimulated innovation in launch vehicles, leading to huge reductions in launch costs, a consequent boom in commercial satellite deployment, and the start of space tourism. Digital electronics is utterly ubiquitous in space applications. It provides essential services for system monitoring and control, mission-specific data collection and analysis and for communication. With rising data volume and the need for space-based edge computing, the demands on the core technology that underpins digital electronics are increasing. Ideal space-based electronics should be reliable, radiation-hard, able to tolerate extremes in temperature and ultra-efficient. While the ambient temperature in space is ~3 K, temperatures can increase enormously in direct sunlight, making components that can work in a wide range of temperatures highly advantageous.

Space and defence drove technological advances in semiconductors and 'chips' in the latter part of the 20th century, but the ubiquitous nature of electronics and computing in all aspects of modern life means that innovations are now driven by consumer applications. The electronics in space market is valued at $2.9 bn, but that is just 0.2% of the $1,497 bn global electronics market. Notwithstanding recent impressive reductions in launch costs, any potential solutions for reducing power demand by electronics, and thus battery or solar cell capacity are highly advantageous. This presents an opportune moment for a technologically- and commercially-disruptive innovation in (digital) electronics that meets the needs of the space sector.

ULTRA**RAM** is an emerging memory with an extraordinary set of characteristics that make it very attractive for space applications: intrinsically fast, ultra-efficient, and with high program/erase cycling endurance, properties required for random-access memory (RAM). Furthermore, ULTRA**RAM** has other characteristics that could be exploited in as yet unimagined ways by creative space scientists and engineers. These characteristics are beneficial in a number of specialist as well as generic applications, but space is the only sector that could benefit from its full range of extraordinary properties.

Non-volatility. Emerging memories such as magnetic random access memory (MRAM) outperform flash, but can't compete with DRAM. ULTRA**RAM**'s intrinsically sub-ns switching speeds and high endurance promises a high-performance RAM that is immune to intermittent or extended periods without power; highly advantageous in space applications.

Ultra-efficiency. DRAM requires constant refreshing, consuming energy and degrading overall system performance. ULTRA**RAM** eliminates this. Also, its switching energy is 100× lower than DRAM, 1,000× lower than flash and ≥10^4× lower than emerging memories. It is estimated that ULTRA**RAM** could deliver energy savings of between 20% and 40% from a combination of direct energy savings on the RAM chip and improvements in overall computing efficiency. Smaller power requirements reduce battery and/or solar panel payload and lower launch costs. Commercial communications satellites typically cost £5M to launch by a Falcon 9 rocket. ~30% of the payload weight is batteries and solar panels, so switching to ULTRA**RAM** would save £0.3M on launch costs.

Temperature tolerant. While the ambient temperature in space is ~3 K, temperatures can increase enormously in direct sunlight, making components that can work in a wide range of temperatures highly advantageous. Preliminary results show that ULTRA**RAM** remains non-volatile at 100°C and indicate that it can operate at <3 K.

Radiation hardness? This will be robustly tested to ESA standards later in the year. However, we know that ULTRA**RAM** is defect tolerant because every protype device has hundreds of defects due to the lattice-mismatched epitaxy of their production. Furthermore, we have observed that while intense visible illumination changes readout current, it does not affect the memory state. Both observations imply excellent radiation hardness.

2. Engagement with the space sector

We continue to engage across the space sector. These interactions are briefly described below, in alphabetical order.

Axiom Space, Houston, US [https://www.axiomspace.com/]

Axiom Space is the leading provider of human spaceflight services and developer of human-rated space infrastructure. They operate end-to-end missions to the International Space Station (ISS) while developing its successor, Axiom Station, and building next-generation spacesuits for low-Earth orbit, the Moon and beyond. They recently successfully completed Axiom Mission 3 (Ax-3), the first all-European commercial astronaut mission to the ISS. Ax-3 marked a new era of opportunity for countries to join the international space community and access low-Earth orbit to advance exploration and research in microgravity.

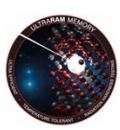
Initial contact with Axiom came via a Call from the Department of Business and Trade for a visit to Axiom in Houston in February. We were selected by Axiom for the visit, but ultimately did not attend as developing our interaction online was working well. Indeed, meetings with Axiom are regular and ongoing, with the review of an NDA currently pending. Axiom are particularly interested in our materials expertise, with high-value in-space manufacturing in mind. Given their role in ISS and in the development of its commercially-built successor a partnership with them is clearly a significant endorsement and provides a route into the space sector for the company.

Cobham Advanced Electronic Systems (CAES) Virginia, US [https://caes.com/]

Frontgrade, Colorado Springs, US (HQ); Exeter, UK; Gothenburg, Sweden [https://www.frontgrade.com/]

CAES and Frontgrade design, test and manufacture advanced electronic solutions for the aerospace, defence and space industries. They partner with technology providers to develop new systems from the ground up, including memory systems. Note: Frontgrade was previously CAES Space Systems but is now an independent company.

We were invited to present our technology on a video call, which was very well attended by Directors of the Space Microelectronics, Engineering and Space Strategy divisions, as well as application engineers and product marketing managers. They were very interested in ULTRA**RAM** and its unique properties which they identified would reduce system weight, launch costs and allow instantaneous shut down/startup. We discussed radiation hardening, high



temperature operation and system integration. John Mabra, Director of Engineering, said that they were certainly interested in collaboration as we progress to higher TRLs.

Frazer-Nash Consultancy, Surrey, UK [https://www.fnc.co.uk/]

Frazer-Nash Consultancy is a leading systems, engineering and technology company with expertise in space applications. They design and build space systems for defence, communications and solar power.

Conversations with James Cornish, Space Business Manager, confirmed ULTRA**RAM**'s potential for space applications. He was particularly enthusiastic about ULTRA**RAM**'s energy efficiency, which could greatly reduce satellite weight and launch costs. They are knowledgeable in space standards and can help us meet those requirements. They are interested in collaborating and have offered to help identify funding streams for the spinout. They suggested jointly applying for grants, *e.g.* from the UK Space Agency (UKSA), to fund a mission to launch a cubesat containing ULTRA**RAM**, to demonstrate its suitable for space applications. Indeed, we already submitted a bid to the UKSA (NSIP Kickstarter), which, unfortunately, was not funded, so we are on the lookout for further opportunities.

Open Cosmos, Didcot, UK [https://www.open-cosmos.com/]

Open Cosmos design, manufacture, test and operate satellites. Their launches include earth observation for environmental monitoring, positioning/navigation systems and satellites providing connectivity for ground-based sensors. Their satellites mainly operate in low Earth orbit (LEO) where the environment is more benign and radiation hardened electronics are not required.

We have discussed ULTRA**RAM** with Jordi Barrera Ars, co-founder and VP Technology, who identified our technology's energy efficiency and non-volatility as valuable characteristics for their satellites. They confirmed that state-of-the-art cell sizes are not necessary for space applications, with larger cells being more robust against single event bit flips. They have expressed interest in using our ULTRA**RAM** memories once we have a close to commercial product.

Satellite Applications Catapult, Didcot, UK [https://sa.catapult.org.uk/]

The Satellite Applications Catapult is at the heart of the UK's satellite services revolution, driving take-up of space technology and applications to shape, and sustain, the world of tomorrow. It is driven to help the organisations it works work with, both large and small, bring new services to market. By connecting industry and academia it gets new research off the ground and into the market more quickly.

We worked with the Satellite Applications Catapult, through the Business & Innovation Directorate of the Science and Technology Facilities Council, to contribute to the 'position paper', *'Why space? The opportunity for materials Science and innovation'*, on the use of materials and associated technologies in space. Our contribution briefly described the wider opportunities for compound semiconductors in space, but with a particular focus on ULTRA**RAM**. We were also selected to do a short talk at the official launch event of the paper at the Royce Institute in Manchester in March. The 'Why space?' paper can be found here.

Thales, Brighton, UK (Multinational) [https://www.thalesgroup.com/en]

Thales is a global technology leader that invests in digital and deep tech innovations. They provide products and services in the markets of defence, aerospace, space, digital security and transport.

We are in contact with Peter Davies, Technical Director, who was impressed with ULTRA**RAM**'s energy efficiency, which would be useful in a range of their sectors, particularly space and defence. They have expressed an interest in collaborating with us and have said that they can support us at all stages of technology development.

University of Wollongong, New South Wales, Australia [https://www.uow.edu.au/]

We are working with Prof Michael Lerch of University of Wollongong through an ongoing Lancaster University research project (ULTRARAM - ATTRACT Project phase 2 (attract-eu.com)), which predates Quinas incorporation. They provide expertise in radiation hardness testing, and will be testing ULTRA**RAM** against European Space Agency standards for total ionising dose (ESA standard 22900) and single event effects (ESA standard 25100) later in the year.

9th April 2024