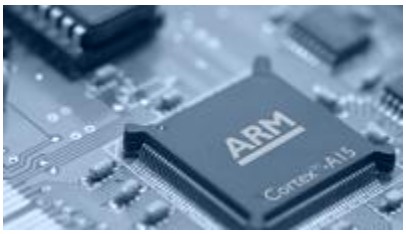
Introduction



Using a laptop computer, Smartphone or iPad has become an essential part of everyday life for many people. Few, however, will be aware of how the technology that drives these tools is created.

ARM is the world's leading semiconductor intellectual property (IP) supplier. Intellectual property is that which originates in the mind such as ideas, literary works, music and designs. ARM's business model is not typical. It does not own any factories but instead designs and licenses its technology to a network of partners who carry out the manufacturing. Over 900 licenses have been sold to more than 250 different partner companies. These include the world's leading semiconductor and systems companies, such as Samsung, NVIDIA, Texas Instruments and Qualcomm.

From its founding in 1990 in Cambridge in the UK, it has grown to become a major developer of digital electronic products. The company has offices around the world, including design centres in the UK, USA, India, Scandinavia, France and China.

ARM is a Research & Development (R&D) focused business. Its 'products' are intangible and cover a diverse range of applications. They are used in everything from sensors to servers. Mobile phones, tablet computers, washing machines, car braking systems and network routers all use ARM technology. In return for its technology, ARM receives a license fee for the original IP from the partner and a royalty on every microchip produced. To date, over 20 billion chips containing ARM technology have been manufactured.

ARM relies on the high levels of creativity, innovation and knowledge of its people to continue to develop new ideas and provide customers with the benefits of emerging technology. Its R&D activity is collaborative and generates innovation in other companies. For example, leading brand Smartphones contain ARM technology that has been incorporated into chips manufactured by a variety of semiconductor companies. In turn, they use diverse software and applications running on various operating systems such as Android. This sharing of information contributes to increasing the industry's knowledge base.

This case study will look at the processes of research and development at ARM and show how these support the company's leading market position.

New product development (NPD)

New products may stem from invention or innovations. Invention is the formulation of new ideas for products or processes. Innovation is the practical application of new inventions into marketable products or services.

Product development may follow different routes:

- A **product-orientated** approach is where a company develops a new product. It then seeks a market and 'pushes' the product out to that market. This might be to solve a problem or to take advantage of an opportunity. An example could be developing new functions for mobile phones. This is a higher risk approach as the company will carry the costs of development without knowing what the returns might be.
- A **market-orientated** approach develops a product to meet a known current or future customer need. This need would have been identified through market research. Developing a product to specific requirements may reduce costs and increase the probability of product success. Having a market waiting to buy the product gives assurance of return on the investment.

  Responding to **competitor** products allows a business to catch up or overtake business rivals. This development may lead to a better product.

- **Changes in technology** may lead to the development of a more effective product or one which sets a new benchmark for the market. For example, the Amazon Kindle is changing the way people read books.

ARM adopts a route of innovation to transfer its technology into products customers want and need. Its technology supports three key types of chips:

A - class processors (applications)	These are equivalent to PC processors; these are 'high end' and are used in everything from smart phones to servers and supercomputers where multi-tasking is needed.
R - class processors are 'real-time'	These are embedded in things and do only one job, such as the overall braking control on a car.
M - class processors (micro controllers)	These are general purpose and programmable. They are used for a single less complex task or a larger process. These are used in, for example, washing machine programmes or on the ABS brakes on each wheel of a car.

External influences

ARM's product development also takes various external factors into account, for example, the need to develop low carbon products, increase energy security and address impacts on global warming. In addition, meeting global economic challenges is also high on ARM's agenda. For example, developing countries such as Brazil and China are becoming more affluent and buying more consumer electronics.

Other factors affecting ARM include the customer's desire for greater computing mobility, lower power consumption and increased battery life. Consumers are also looking to 'cloud' technology, for example, in mobile phone apps, to provide remote access to virtual storage and software. This provides convenience and lower cost.

ARM's main technical driver is power efficiency, making microchips smaller whilst increasing their performance. The smallest processors are now the size of human hair or crumbs.

Research

The research process involves inquiry into and discovery of new ideas to solve a problem or create an opportunity.

ARM invests around £140 million per year into its research programmes. As a knowledge-based research and development business, the majority of costs are associated with the company's high quality employees.

ARM's corporate R&D	This looks 5-10 years into the future for new ways to do things. It also considers future products.
ARM's advanced product development	This is concerned with how to apply new technology 3-5 years in the future.
ARM's product development	This is focused on new products for launch in 1-2 years.

Push or pull?

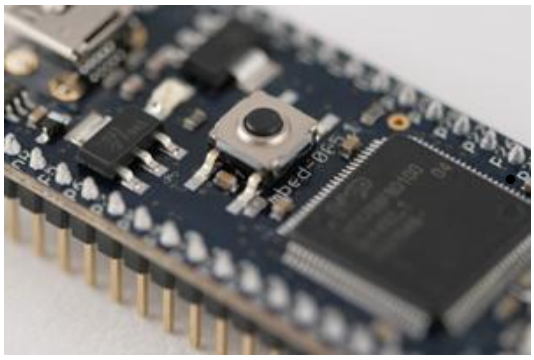
ARM's R&D is predominantly market-orientated. It is influenced by feedback from hundreds of customers – and their customers – from different industries and with different needs. ARM employs a 'Push/Pull' model.

- The push is where ARM puts its latest developments out to manufacturers to drive new technical innovations.
- The pull reflects what customers and consumers are asking for, i.e. market demand. ARM's R&D team talks to people at every level within key industries to establish what they need and what demand there is for different products in order to ensure products are customer-orientated.

External influences also affect ARM's research. For example, energy efficiency is high on the public agenda. R&D into low power techniques

has always been a key focus for ARM. The microprocessor market is now focused on evaluating the benefits of similar products across competitors. For example, which has lowest power, highest performance (speed) and the smallest scale (which is vital for mobile devices).

Development



Development involves transforming ideas into a product fit for market. From numerous ideas at the research stage, ARM will take only a few with potential into the development stage. The key elements of the development process include:

A product brief – identifying what market need it fills. To produce a product brief, ARM works with around 1,000 companies. These companies may be ARM customers, competitors and collaborators all at the same time. ARM's engineers talk to partners who make the microchips to establish what is possible technically and its market-focused people identify what the market is asking for.

- A product specification – outlining the main features, benefits and costs. ARM combines this feedback and establishes priority needs. These are then evaluated to focus on the application which will lead to a deliverable product.
- A process of evaluating alternative solutions – through computer modelling, samples or prototypes. ARM will select lead partners for specific projects. The partners' R&D teams then work with ARM's R&D team to develop the initial idea.
- A sequence of testing – to check the product meets requirements. Once tested, the design is then licensed to the partners to manufacture, on which ARM receives royalties.

Development of the Cortex-M0+ processor

The development of ARM's Cortex-M0+ processor, which was released in early 2012, is a world-leading innovation. It has the lowest energy consumption of any processor and generates low carbon.

The Cortex-M0+ (M class) is a very simple processor. However, its profile reflects the concept of 'machine to machine communication'. It is believed that this is the next major step in technology. For example, it could automatically control a fridge's temperature depending on whether it is full or empty.

Typically projects take around 18-24 months. However, the Cortex-M0+ had a relatively short timescale. Initial conception of the idea was in December 2010. The project team was set up in April 2011 and delivery to the customer was in February 2012 – just 10 months of development time after the specification was finalised. The ARM team involved is proud of achieving completion to such a tight timescale.

Project planning

The project path followed a clearly defined structure:

- The idea was generated via the feedback from product managers and the marketing managers.
- An outline product specification was devised by working with the lead partner Freescale.
- The project team of three key people including a Project Manager was created. The project team determined the required team size, estimated schedule, agreed stages and milestones to meet customer requirements. The project approval also included deciding how Cortex-M0+ would fit into the existing ARM 'roadmap' (or timetable) of products already underway and planned for the future.

ARM's typical project process gives opportunity for lead partners to add their influence or interact with the product development team. This might include changing the specification or having early access to the product for testing.

Freescale was given access to Cortex-M0+ at the beta design stage. This enabled them to develop a prototype which could be demonstrated at conferences and to key customers. This generated early interest in the product and reduced the time to market, which increases the revenue potential for ARM and Freescale.

Challenges and benefits of R&D

The challenges of a typical R&D process include:

- large costs – of people, time and equipment
- long timescales – for example in the pharmaceutical industry it can take as long as 10-20 years to complete full testing
- high risk – difficulties in anticipating changing market and consumer needs over the duration of R&D projects, which leads to uncertain outcomes.

ARM meets these challenges and reduces the potential risk of its projects by:

- working with lead partners to understand what is technically possible
- listening to what its customers and their customers are asking for
- managing timescales by adjusting the team size and ensuring the right skills are in place in order to deliver on time.

ARM's challenges

Challenges to R&D at ARM are mainly technical or economic. Moore's Law describes the shrinking process of technology. Moore's Law is named after Intel co-founder Gordon E. Moore and predicts that the number of transistors on an integrated circuit (and therefore its performance and capability) will double approximately every two years. The law is used in the semiconductor industry to guide long-term planning and to set targets for research and development.

However, it is not possible to shrink things forever and the smaller technology gets, the more complex microchips become. As technology becomes more complex, ARM requires more people to carry out the work. As chips get more complex, the skills required for the work are more intricate.

This human element becomes a real challenge for ARM due to the specialist nature of the work teamed with a global skills shortage. It also brings challenges of communication between stakeholders because of the mix of geography, culture and time zones within which ARM operates.

Ongoing need for skills

ARM has a continual challenge in recruiting skilled people. It has ongoing recruitment and offers internships each year to attract the best skills. It has employed around 400-500 people in the last year. ARM provides an exciting, collaborative and team-based environment.

Training for new graduates involves rotation across several projects to develop skills rapidly. Although needing very high levels of skills to enter the business, once in the organisation, ARM people are highly employable.

ARM's approach to R&D delivers significant competitive advantage. Its unique, world-leading products and technology enhance the business' reputation and ongoing research generates opportunities which keep its product pipeline strong. ARM's business model enables the business to gain the potential to earn future income over many years from licensing its intellectual property.

Conclusion

R&D supports invention and innovation. ARM, as a market-orientated business, relies on innovation to maintain its market-leading position in an industry focused on advancements in technology.

Through the use of feedback, from both technical experts and customers, ARM ensures its product development reflects market demands. Its partnership approach reduces risk whilst minimising the time it takes to get a product to market.

ARM's ongoing recruitment cycle helps ensure it has employees with the required specialist skills and competencies to maintain its position in the market. This is an ongoing challenge due to the complexity of the work. 95% of ARM's workforce is made up of graduates, with around 70% of these being educated to Masters degree level or higher. Although entry levels are high, the innovative nature of the work offers a highly creative and rewarding environment.