

Allied Minds

Portfolio rebased for growth

Allied Minds' portfolio has been significantly rationalised since 2017, with the portfolio now focused on six principal companies. Management expects the top three companies to achieve commercialisation in 2019, and we believe there could be substantial upside if this is achieved. The shares trade at 0.41x H118 NAV (adjusted for latest net cash). Allied Minds' enterprise value (market capitalisation less parent cash) trades at a 45% discount to our valuation for the top four portfolio companies, each of which has been validated by external fund-raising. Following recent cash management measures, management believes that Allied Minds' cash runway has been extended into 2021.

Period end	Ownership adjusted value (OAV) (US\$m)	Parent-level net cash (US\$m)	NAV (US\$m)	NAV/share (p)	P/NAV (x)
12/16	415.8	136.7	552.9	208	0.25
12/17	395.6	84.2	479.8	150	0.35
06/18	350.1	50.0*	400.1	127	0.41

Note: NAV is calculated as OAV plus net cash at parent level. *Allied Minds' estimate of end FY18 net cash.

Strategic investors underline value

After the rationalisation of the portfolio in 2017, the six principal companies, in the space, connectivity/5G and medical devices sectors, comprise 92%+ of portfolio fair value. Allied Minds' EV trades at a 45% discount to our valuation for the top four portfolio companies, each of which has been validated by external fund-raising. Funding rounds have been led by major independent strategic investors, at Spin Memory (Arm, Applied Materials), HawkEye 360 (Raytheon), BridgeSat (Boeing) and Federated Wireless (Charter, Arris, American Tower). However, despite recent bridging rounds, third-party validation is still pending for two of the six principal portfolio companies, Precision Biopsy and SciFluor.

Targeting premium exit valuations

Ultimately, Allied Minds' value will be determined by a small number of premium exits. CEO Jill Smith is focused on driving commercialisation at the top businesses and investing selectively in the pipeline. The group's priorities include attracting strategic investors, strengthening leadership and governance across the portfolio, while focusing on thematic investing. Subsidiary management teams have been strengthened and are aligned and accountable for achieving clear milestones. Management estimates end-FY18 parent cash to have been \$50m which, following cost management measures, it deems sufficient to fund the businesses into 2021.

Valuation: 59% discount to NAV unwarranted

Allied Minds' share price has fallen by 72% since its portfolio write-down announced on 5 April 2017. The company's shares now trade at 0.41x H118 NAV even though c 64% of H118 NAV is either in cash or has been validated by strategic co-investors. Our bottom-up analysis of the six core assets suggests meaningful upside potential once key milestones are achieved (particularly at Federated Wireless, Spin Memory and HawkEye 360). This level of discount to NAV appears unjustified. However, we note that Allied Minds has yet to exit any investments.

Initiation of coverage

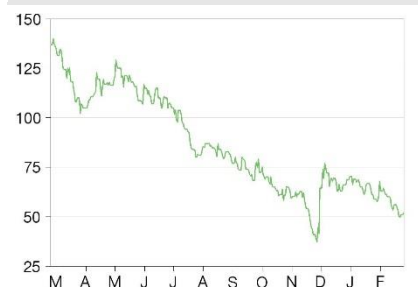
Investment companies

26 February 2019

Price **52.1p**
Market cap **£125m**
 £/US\$1.31

OAV (\$m) at 30 June 2018	350.1
NAV (\$m) at 30 June 2018	400.1
Shares in issue	240.3m
Free float	91%
Code	ALM
Primary exchange	LSE
Secondary exchange	N/A

Share price performance



%	1m	3m	12m
Abs	(11.7)	27.1	(62.0)
Rel (local)	(15.9)	23.0	(61.5)
52-week high/low	140.0p	37.3p	

Business description

Allied Minds is an IP commercialisation company focusing on early-stage companies within life sciences and technology. Its portfolio companies are spin-outs from US federal government laboratories and universities. The top six holdings comprise 92%+ of portfolio fair value.

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Introduction: IP commercialisation

Seeking returns through premium exits

Allied Minds is an IP commercialisation company (IPCC) focused on early-stage company creation and development within the technology and life sciences sectors. The group is based in Boston, and all the current portfolio companies originate from US federal laboratories and universities. Allied Minds was founded in 2004 and listed in London in 2014.

The company's first investment was in 2006, with multiple direct investments made by Allied Minds, accompanied by additional funding rounds from strategic investors. As at June 2018, approximately \$405.1m had been allocated to active portfolio companies, of which \$170.5m was deployed by Allied Minds and \$228.3m contributed by third-party investors. The remaining \$6.3m was raised in the form of bank loans and federal grants.

The group currently comprises 11 active portfolio companies (although, following its latest review, management does not expect to allocate further funds to either LuxCath or Signature Medical), of which it holds a controlling stake in seven and substantial minority positions in the remaining four.

The group's overall strategy is to deliver attractive returns, as well as to generate additional sources of funds for company creation and development by realising superior exit valuations from the portfolio businesses that achieve commercialisation. It is seeking to:

- **accelerate** the path to commercialisation and monetisation at its top six portfolio companies;
- **nurture** the progress of its earlier-stage companies; and
- **grow** a new opportunity platform by increasing the number of high-quality new investments.

At June 2018, Allied Minds reported an estimated group ownership adjusted value (OAV) of \$350.1m, which compares to \$395.6m in FY17 and \$415.8m in FY16. As we detail below, the decline in OAV since 2016 was substantially due to the liquidation of a number of portfolio businesses (Percipient Networks, Seamless Devices, Whitewood Encryption), meaning that currently 92%+ of portfolio fair value is derived from six key companies. Valuations at Spin Memory (reflecting the expected term sheet), Precision Biopsy and SciFluor were rebased at H118 following reductions in their DCF valuations.

At June 2018, Allied Minds had net cash of \$132.2m, of which \$66.0m was held at the parent level. This compares to \$169.1m group cash and \$84.2m parent cash at FY17. Since June 2018, Allied Minds has invested a further \$14.3m (up to \$16.8m depending on residual Spin Memory subscription), with estimated parent level net cash of c \$50m at end FY18, which the company believes is sufficient to fund the business (both existing and origination) into 2021. Following the announced cost reduction initiatives, our estimates assume c \$20–25m total cash is spent in FY19 and FY20, covering further funding rounds, investments and cash burn at the parent.

Taken together, Allied Minds believes these measures should allow it to extend its cash runway into 2021, before any potential returns from monetisations.

Investment case summary points

- The US is the largest R&D market in the world and Allied Minds' breadth of relationships with US federal laboratories and universities provides a key competitive advantage.
- Thematic investing enables Allied Minds to concentrate on areas of expertise.
- Six mature, promising companies comprise 92%+ of the estimated portfolio fair value.
- Four of these companies (Federated Wireless, HawkEye, BridgeSat and Spin Memory) have now been validated by strategic co-investors, meaning that c 64% of H118 NAV is either in cash or has been validated by strategic co-investors. The strategic co-investors should provide significant commercial benefits to these companies.

- Management expects commercialisation of the top three technology businesses in 2019, which could provide an uplift to portfolio fair value.
- Allied Minds' EV is at a 45% discount to our valuation for the top four portfolio companies, each of which has been validated by external fund-raising. In our view, the current valuation ascribes limited upside to the recent strategic partnerships, as well as little or no value to the core life sciences subsidiaries.

New management, portfolio consolidated

2017 was a period of significant change for the company, with a new CEO (Jill Smith) instigating a rationalisation of the portfolio. The group's strategic priorities include focusing on attracting strategic investors, a strengthened leadership, improved governance and a thematic approach to investing. The newly concentrated portfolio comprises six principal portfolio companies in the space, connectivity/5G and life sciences sectors. Allied Minds believes all six businesses have innovative and potentially disruptive technologies, each with a meaningful line of sight to commercialisation. We summarise the companies in Exhibit 1 below, with more detailed individual analysis on pages 15–50.

The group has either large minority or controlling stakes in all of these businesses, ranging from 41% (anticipated Spin Memory holding post second closing) to 81% (BridgeSat). These core businesses comprise substantially all of portfolio fair value. As a result of clinical delays, both SciFluor's and Precision Biopsy's holding value were reduced through a DCF revaluation in H118 (reflecting delays in clinical trials) and received bridge financing to their next rounds, provided jointly by Woodford and Allied Minds. Spin Memory's valuation was also reduced in anticipation of an imminent funding round (now closed).

The company has focused on making new investments, primarily within its existing spheres of expertise (space, connectivity/5G and medical devices). This is exemplified by three new investments in 2018 (TableUp, Orbital Sidekick and QuayChain).

Outside the six main holdings, Allied Minds has two other early-stage medical devices investments (LuxCath and Signature Medical) where commercialisation remains further off. However, as part of its cash management strategy Allied Minds has determined to seek strategic alternatives for these earlier-stage life sciences businesses, and does not expect to allocate further funds to them. Consistent with Allied Minds' historical approach, for the purposes of our model, we have chosen to write down the value of these investments, although value may still be realised through future investment or sale of the businesses.

Proactive cost management to extend cash runway into 2021

As mentioned above, in its 7 February 2019 trading update ahead of its FY18 preliminary results, recognising the challenging capital markets environment for the firm, Allied Minds announced a number of cost management measures. These included:

- annualised central cash operating expenses to be reduced by \$5.6m (c 40%);
- the CEO, Jill Smith, to materially reduce her cash salary for 24 months, commencing FY19, with the balance to be deferred into 2021 – any earned bonus for 2019 and 2020 to be satisfied in shares rather than cash; and
- no intention to allocate further funds to its earlier-stage life science businesses, LuxCath and Signature Medical, instead seeking strategic alternatives for these businesses.

The net result of these measures is to extend Allied Minds' cash runway into 2021, before any potential returns from monetisations.

Ownership adjusted value (OAV)

Ownership adjusted value represents management's assessment of fair value for the portfolio companies, considering Allied Minds' interest in the equity value of each subsidiary.

OAV is calculated as follows:

$$\begin{aligned} \text{OAV} &= (\text{business enterprise value} - \text{long-term debt} + \text{cash}) \\ &\times \text{Allied Minds' percentage ownership} \\ &+ \text{the value of parent company debt to each company.} \\ \text{NAV} &= \text{OAV} + \text{parent net cash} \end{aligned}$$

Practically, as determined by management, portfolio companies are held at:

- the valuation of the last round of financing (eg Federated Wireless, HawkEye, BridgeSat and Spin Memory);
- a discounted cash flow-derived valuation (SciFluor, Precision Biopsy); or
- the value of invested capital (for early-stage assets).

Funding rounds, gaining momentum with strategic investors

Since rebasing the business in 2017, Allied Minds has completed funding rounds, including external strategic investors, for Spin Memory (\$52m), HawkEye (\$14.9m), BridgeSat (\$10m) and Federated Wireless (\$42m). Together with parent level net cash, we estimate that these companies (plus cash) underpin c 64% of H118 NAV (see Exhibits 1 and 38).

Including the most recent Series B round for Spin Memory, the top four technology companies now have very credible strategic investors. HawkEye, Federated Wireless and Spin Memory are poised for commercialisation in 2019 and, although there is limited visibility regarding revenues, clearly this could be the basis for increasing future OAV.

By contrast, Precision Biopsy and SciFluor delayed the start of the next phase of their clinical trials by several months, reflected in a reduction in OAV at H118. In its latest trading statement, Allied Minds has agreed to contribute (jointly with Woodford Investment Management) an aggregate \$9m of convertible bridge financing to SciFluor (\$4m) and Precision Biopsy (\$5m). In the case of SciFluor, the funding is intended to bridge to a Series B round to fund Phase II trials for its SF0166 topical eye drop treatment for retinal disease, as well as to position the company for the growth of its platform. In the case of Precision Biopsy, the financing is intended to bridge to a round to fund its pivotal SCORE study. Neither round includes strategic investors.

However, with Allied Minds' EV at a 45% discount to our valuation for the top four portfolio companies, each of which has been validated by external fund-raising, arguably the upside potential for the top four technology companies and the value of the two core life sciences businesses are not fully reflected in the current share price.

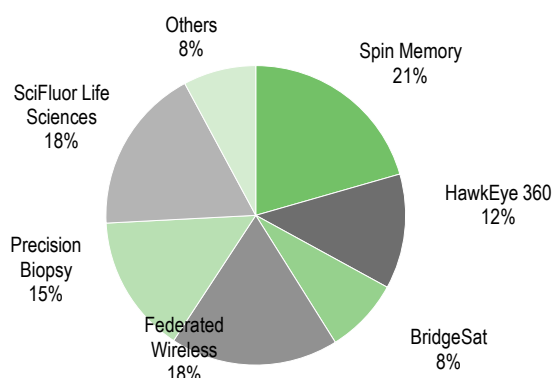
In Exhibit 1 below, we summarise the estimated OAV for each of the core businesses, as well as highlighting key co-investors. The large addressable markets for each division are an indication of the potential within each business, which is further elaborated on pages 15–50.

Exhibit 1: Top six subsidiary businesses

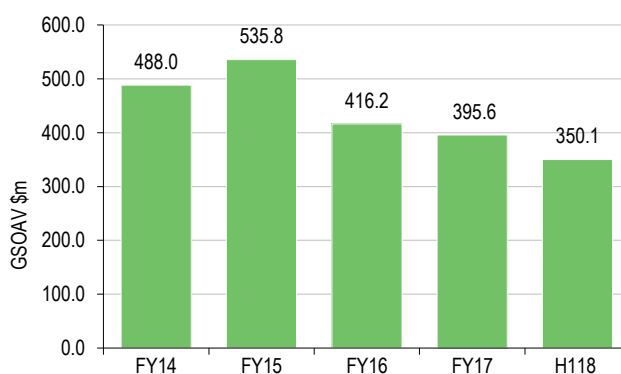
Subsidiary	ALM % holding	OAV* (\$m)	Co-investors	Addressable market**	Recent funding rounds
Spin Memory (2007)	41%***	\$72m	Arm; Applied Materials; Woodford; Invesco	Next-generation semiconductor memory, offering a full suite of MRAM solutions. Estimated \$20bn market.	\$52m Series B round and commercial agreements with Arm and Applied Materials (November 2018)
HawkEye 360 (2015)	48%	\$43m	Raytheon; Razor's Edge; Shield Capital; Woodford; Invesco; Sumitomo	Data analysis of radio frequency signals from its own satellite constellation and third parties for applications including maritime domain awareness. Estimated \$2.4bn market.	\$14.9m Series A-3 round led by Raytheon (September 2018)
BridgeSat (2015)	81%	\$28m	Boeing; Space Angels Network	Optical communications service for transferring data from satellites. Estimated \$1.5bn LEO satcomms market.	\$10m Series B round led by Boeing (September 2018).
Federated Wireless (2012)	52%	\$63m	Arris; Charter; American Tower; Woodford	Shared spectrum cloud-based software platform. Estimated multi-\$bn market.	\$42.0m Series B funding round in September 2017
Precision Biopsy (2008)	65%	\$52m	Woodford	Real-time tissue characterisation. Estimated \$4bn market (US and EU).	
SciFluor Life Sciences (2010)	70%	\$63m	Woodford; Invesco;	New ophthalmology drugs. Estimated injectables market \$8bn.	

Source: Company accounts. Note: *Edison estimates based on previous funding rounds as well as recently updated group OAV.

Allied Minds estimated addressable markets for its products. *Allied Minds anticipates holding 40.88% of Spin Memory's equity post second closing of the latest November 2018 investment round.

Exhibit 2: OAV analysis by portfolio holding


Source: Company accounts, Edison Investment Research

Exhibit 3: OAV progression (\$m)


Source: Company accounts, Edison Investment Research

Valuation: Potential in core assets not reflected in NAV

NAV analysis: Trading at 0.41x H118 NAV (adjusted for latest cash)

Over the past decade, the markets have become more familiar with the IPCC sector. Up to 2017, shares generally traded at a significant premium to NAV. However, like many of its peers, Allied Minds' premium to NAV peaked in 2015, with investors anticipating healthy IRRs across the board, subsequently declining to the point where shares now trade at a discount to NAV.

Since its announcement in April 2017, when the company wrote down or liquidated a large proportion of its portfolio, Allied Minds' shares have fallen by 72% and now trade at a meaningful discount to H118 NAV (0.41x). This compares to its peers such as IP Group at 0.84x and Mercia Technologies at 0.91x, suggesting that investors lack confidence in the portfolio OAV.

We would argue that at the current level, Allied Minds' shares potentially offer value, given that c 64% of NAV is either in cash or has been validated by strategic co-investors.

Looking forward, increases in OAV are clearly hard to predict, but catalysts include further funding rounds, as well as commercial progress across the portfolio.

Market data: Showing what success could look like

Our analysis of the six core assets suggests there is significant upside potential. In each case, we have detailed some of the necessary milestones and operational goals required to unlock value.

However, it is important to note that in all cases, the early-stage nature of these companies makes it impossible to articulate a precise valuation range.

To demonstrate what success might look like for the most promising top three technology businesses (reaching commercialisation in 2019), we have highlighted some market data and/or comparable companies to provide a benchmark for valuation. We provide a summary here, but please see the individual company analysis for more information.

Federated Wireless (18% OAV)

In our view, the most significant opportunities lie in Federated Wireless, with growth opportunities following the important investment from Charter Communications in September 2017. At this early stage, it is very difficult to assess the potential value of Federated's software platform, but using the company's market forecasts and applying our own assumptions suggests a business capable of generating nearly \$100m in revenue and \$30m in profits by 2022.

Spin Memory (21% OAV)

Spin Memory's management has not provided any guidance on how revenues may develop. However, it is possible to make comparisons with other public companies; for example, Arm's licence model was based on 2% per chip sold, with the company acquired by SoftBank at a valuation of 24.4x historic revenues. Applying these metrics to our \$176m estimate of Spin Memory's valuation (recognising that these multiples represent the top end of a range) indicates licensing revenues of \$7.2m from supplying IP for \$360m worth of MRAM chips. This is equivalent to c 1.8% of the estimated \$20bn TAM DRAM substitution market or 7.5% of the more conservative \$4.8bn estimated MRAM market size predicted by Research and Markets.

HawkEye 360 (12% OAV)

Having launched its Pathfinder mission in December 2018 and with its initial three satellites successfully commissioned, HawkEye will derive recurring revenues from providing location and spectral data on radio frequency (RF) signals to subscribers from 2019 onwards. Management believes HawkEye is the only commercial entity that has launched satellite clusters with diverse RF signal detection, mapping and analytics capabilities, including predictive analytics, conferring first-mover advantages. As this is a new market, there are no data available on its size. Management notes that, according to P&S Market Research, the commercial satellite imagery market is forecast to be worth US\$6.9bn by 2023, indicating that there is considerable potential value in commercialising other forms of space-based data collection and analytics. We note that DigitalGlobe (Jill Smith was previously CEO up to 2011, including at the time of its 2009 IPO), a global commercial provider of earth imagery and geospatial content that operates its own commercial remote sensing spacecraft, generated US\$725.4m in revenues in 2016. It was acquired in February 2017 at an equity value of approximately US\$2.4bn.

Investment process, value-add, exit strategy

IPCC general characteristics

IPCCs are open-ended or evergreen funds, focused on funding university or other institutional (eg US federal research facilities) associated start-ups, whose inventions often require significant development before becoming commercially viable (10+ years, compared to five to seven years for classic venture capital (VC) funds). IPCCs typically enter at seed or Series A investment rounds and continue to protect their equity positions through follow-on investment. The initial seed round is typically small, with additional investment only made on achievement of certain milestones. Throughout the lifecycle, IPCCs are hands-on investors, providing an appropriate level of management, operational and governance support and expertise. Although historically it has taken

majority stakes, Allied Minds has recently stated that it will now also consider minority stakes where appropriate (typically at the Series A stage), and has subsequently taken substantial minority stakes in Orbital Sidekick and TableUp.

IPCCs do not have the fixed-term investment period of classic VCs or closed-end funds. Instead, they reinvest proceeds into new start-ups and their existing portfolio of companies to make returns over longer, open-ended periods. The thesis is that this long-term approach (characterised as 'patient capital') will lead to higher returns. By investing from their own balance sheets, IPCCs are not under pressure to return capital to shareholders within a specific period, thus enabling further growth and nurturing of their portfolio businesses. Many IPCCs have supportive shareholders such as Woodford and Invesco which, as well as holding shares in the parent company, have regularly co-invested in spin-outs.

Higher than average risk/reward

Given the possibility for technological breakthrough, investments carry significant potential upside, but also have a higher commensurate risk. To minimise sunk capital, IPCCs often write off companies at an earlier stage than VC firms. As such, a key component of the IPCC strategy is to maintain strict discipline in the allocation of financial and human capital to those businesses meeting milestones as well as to terminate funding for those IPs/businesses where the path to commercialisation is no longer attractive.

Working towards a premium exit

The IPCC business model is predicated on the assumption that only a small minority of premium exits will drive overall investment returns. The key for all these groups is to set up conditions for a premium exit from those companies that can successfully reach commercialisation.

Allied Minds' strategy

Allied Minds' strategy is to accelerate the path to commercialisation/monetisation at its top six companies, nurture progress at earlier-stage companies and grow its new opportunity platform by increasing the number of high-quality investments. In this section, we outline the key components to achieve these goals.

Working in the US: The largest R&D market in the world

While other listed IPCCs predominantly focus on UK universities, Allied Minds' portfolio is entirely derived from the US, which boasts the largest R&D market in the world. The group collaborates with selected US federal research institutions, universities, medical institutions and others to identify early-stage innovations that have the potential to transform markets and to invest to build strong companies that bring differentiated products and services to market.

The group is increasingly focusing on building on its relationships with the various federal laboratories, which are typically less competitive than universities; this is a key differentiator versus its peers. Federal research is often commissioned with a particular US government (usually military or intelligence) application in mind. The technology therefore has a purpose or application that can be opened up to dual government and/or commercial use when licensed. IP is typically more proven and advanced versus university research. The technology underlying Federated Wireless is a good example – the work done at Hume Center for National Security, Virginia Tech, was undertaken in response to an Obama era edict soliciting technological solutions from the research community to enable spectrum sharing.

Thematic approach: Focused portfolio

CEO, Jill Smith, has reiterated the importance of thematic investing, focusing on theses and areas of competitive advantage. The investment pipeline has been enhanced by fostering deeper

(although non-exclusive) relationships with a smaller number of research institutions aligned to Allied Minds' existing sphere of expertise. The aim is to create winners in new or emerging markets, where the group has an established reputation, network and proprietary insight. In particular, management is increasingly focusing on US government laboratories, and other federally funded research and development centres.

Allied Minds' three main areas of expertise are:

1. Space (HawkEye, BridgeSat, Orbital Sidekick).
2. Connectivity/5G (Federated Wireless, BridgeSat, TableUp, QuayChain, HawkEye).
3. Machine learning-based medical devices/wearables (Precision Biopsy, Signature Medical).

As outlined at the capital markets day in January 2018, the group specifically targets businesses with the following characteristics:

- **Disruptive innovation:** solving a critical problem and preferably first to market, eg HawkEye's RF/geolocation.
- **Favourable market dynamics,** eg Spin Memory with a c \$20bn market opportunity (management estimate).
- **Sustainable competitive advantage with high barriers to entry,** eg SciFluor (eye drop vs injection, with heavy patent protection).
- **Route to widespread adoption** with known distribution channels, scalability and high-margin potential, eg HawkEye's relationship with the US government, supported by its commercial partnership with Raytheon.

Accountability and aligned management team

In addition to the fundamentals of the portfolio businesses, Allied Minds focuses on supporting a capable management team with aligned interests. Since 2017, the new CEO has sought to strengthen leadership, and enhance corporate governance and accountability at each subsidiary business. This includes the appointment of new CEOs at Spin Memory and BridgeSat, as well as various new board members and advisers across the group (including Bob Dempsey at SciFluor, John Kispert at Spin Memory and Fritz Foley's appointment as a non-executive director at Allied Minds).

Disciplined capital allocation is core to the strategy and Allied Minds continuously evaluates the progress and potential of each business and makes funding decisions based on the achievement of key milestones. Together with portfolio company management, the group defines the critical milestones and measures tangible progress towards commercialisation. We detail these specific milestones on pages 10–14, which include both operational and financial measures. Management is accountable for these milestones, which are developed into annual management objectives (MBOs).

Seeking best partners for path to commercialisation/monetisation

Allied Minds is sufficiently capitalised, with a management estimate of \$50m in cash at the parent level at end FY18, enabling the group to support its businesses into 2021, before any potential returns from monetisations. Throughout the lifecycle of the businesses, the group also seeks early and broad syndication of subsidiaries, targeting financial, strategic and commercial partners. These third-party co-investors help to validate the market opportunity and can provide support to accelerate, expand or de-risk the path to commercialisation. Ultimately, the goal is to set the scene for a premium exit from companies that successfully achieve commercialisation and reinvest proceeds into the remaining portfolio.

Access to strategic investors is a key competitive advantage and recent successes include the \$14.9m Series A funding round for HawkEye, with participation from Raytheon, the \$10m Series B

at BridgeSat, led by Boeing, and the \$52m Series B funding round for Spin Memory, led by Arm and Applied Materials. As well as providing financial and technical validation for the investee companies, importantly, these agreements offer critical commercial advantages in terms of access to the partners' network, their scale and reputation, distribution, marketing and technical resource.

Given the long-term investment horizon, we note that Allied Minds has yet to exit from any of its investments.

Key management

A key catalyst for change at the company was the appointment of Jill Smith as group president and CEO in March 2017. Jill has 16 years' CEO experience at public and private companies, as detailed in the table below. At the group level, other new board members include Fritz Foley (independent non-executive director) and, at the portfolio company level, Spin Memory and BridgeSat have also appointed new CEOs since 2017.

Management remuneration is structured such that variable elements (bonus and long-term incentives) make up a significant percentage of the package. In addition to basic salaries, performance-related incentives include bonuses (from delivery of MBOs) and an LTIP at group level. In the event of a successful subsidiary exit (IPO, trade sale etc), a 'phantom' plan allocates 10% of investment gains to Allied Minds' management and board.

Exhibit 4: Board and management team

Name	Role	Background
Jill Smith	President and CEO (March 2017)	16 years as a CEO at public and private companies, including DigitalGlobe (taken to IPO), eDial, SRDS LP; COO of Micron Electronics. An independent director at Endo International, Gemalto NV and JM Huber Corporation.
Peter Dolan	Non-executive chairman (May 2015)	30 years' operating experience, including CEO and chairman of Bristol-Myers Squibb and Gemin X (VC-backed oncology company sold to Cephalon).
Harry Rein	Independent non-exec director (November 2017)	Extensive experience in the VC sector, most recently serving as general partner for 10 years at Foundation Medical Partners. Previously, he was a founder at Canaan Partners and CEO of GE Venture Capital Corporation.
Simon Davidson	Executive VP technology investments (June 2017)	25 years' experience in technology sector, including managing partner of In-Q-Tel, a US-based strategic investor in innovative technologies for the US intelligence community.
Jeff Rohr	Independent non-exec director (April 2014)	30 years' senior management experience at Deloitte, working across a range of industries.
Kevin Sharer	Independent non-exec director (June 2015)	20 years leading Amgen, the world's largest independent biotechnology firm.

Source: Company accounts

Top six companies comprise 92%+ of H118 NAV

Allied Minds' portfolio comprises 11 businesses (nine excluding LuxCath and Signature Medical – discussed below) in the technology and life sciences sectors. Following the rationalisation of the portfolio in 2017, the majority of resources have been redirected to the six most mature and promising businesses, where management has identified a clearer path to commercialisation/monetisation.

The top six companies represent 92%+ of H118 OAV, with Allied Minds' ownership stake ranging from 41% to 81%. Our bottom-up analysis provides key milestones and operational goals that could unlock significant value across the board. In this section, we summarise the key highlights for the six subsidiaries and provide further details on pages 15–50.

Outside the six main holdings, Allied Minds has two other early-stage medical devices investments (LuxCath and Signature Medical) where commercialisation remains further off. The company has focused on making new investments, primarily within its existing spheres of expertise (space, connectivity/5G and medical devices); this is exemplified by three new investments in 2018 (TableUp, Orbital Sidekick and QuayChain).

As part of the cash management strategy confirmed in its latest trading statement, Allied Minds has determined to seek strategic alternatives for its earlier-stage life sciences businesses, LuxCath and Signature Medical, and does not expect to allocate further funds to them. Accordingly, for the purpose of our report, we have written down the value of these two investments, in line with Allied Minds' historical policy.

Exhibit 5: Estimated ownership adjusted value at H118

Subsidiary company	OAV (US\$m)	% of group OAV
Spin Memory	72	21
HawkEye 360	43	12
BridgeSat	28	8
Federated Wireless	63	18
Precision Biopsy	52	15
SciFluor Life Sciences	63	18
Others	28	8
Total	350	100

Source: Edison Investment Research

Spin Memory (2007)

Spin Memory is an MRAM IP supplier, collaborating with strategic partners to provide next-generation memory technology for applications in AI, ADAS, 5G, IoT as well as other sectors. Spin Memory's disruptive STT-MRAM technologies and products provide SRAM-like speed and endurance to replace SRAM and ultimately DRAM in both embedded and standalone applications.

Funding round (November 2018) and latest OAV (\$72m)

Allied Minds' last reported valuation for its stake in Spin Memory was \$121.5m (October 2014), at which date the total valuation increased to \$248m following a \$70m fund-raise. In November 2018, Allied Minds announced a \$52m Series B funding round led by Applied Ventures, the venture capital arm of Applied Materials, and Arm. The investment was linked to a commercial agreement with Applied Materials to create a comprehensive embedded MRAM solution as well as a commercial agreement with Arm for the licensing of Spin Memory's Endurance Engine design IP to address SRAM applications in systems-on-chips (SoCs).

Based on management guidance on the H118 earnings call, we believe that the pre-money valuation of the November 2018 round was the same as that used for the OAV calculation in the company's H118 results, which was approximately half the \$248m level of the 2014 round. However, the deal will likely provide future benefits through the commercial agreements with Applied Materials and Arm, and so represents a significant milestone in terms of validating the company's potential to grow into this sizeable market opportunity.

Exhibit 6: Spin Memory milestones and objectives

H1 2018 milestone progress update	Edison commentary
<ul style="list-style-type: none"> Spin Polarizer demonstrated 40–70% efficiency gains Endurance Engine shown to increase endurance by up to six orders of magnitude, in line with DRAM Syndication of \$22.8m bridge underwritten by Allied Minds (October 2017). \$10.3m convertible bridge facility with existing shareholders (January 2018) Demonstrate Spin Polarizer and Endurance Engine benefits Broaden and deepen licensee base 	<ul style="list-style-type: none"> Completion of \$52m Series B fund-raising led by Applied Ventures and Arm Commercial agreements signed in parallel with Applied Materials and Arm Operational targets achieved John Kispert added as Chair

Source: Allied Minds

HawkEye 360 (2015)

HawkEye is a data analytics company seeking to commercialise the capability to detect, independently geolocate and analyse diverse radio frequency signals from space, from its own satellite constellation for applications including maritime domain awareness.

Funding round (September 2018) and latest OAV (\$43.4m)

In the recent Series A funding round, HawkEye raised a total of \$14.9m (led by Raytheon) and proceeds will fund a second cluster of satellites for launch in 2019. These will augment the coverage of the initial Pathfinder cluster, which commenced operation in 2018 and were successfully commissioned in February 2019. The transaction was completed at a pre-money valuation of \$75.0m (\$89.9m post money). Allied Minds contributed \$3.8m and holds 48.35% of the equity.

Exhibit 7: HawkEye 360 milestones and objectives

H1 2018 milestone progress update	Edison commentary
<ul style="list-style-type: none"> Two rounds of Series A-3 funding totalling \$14.9m (August and September 2018), including new investment from Raytheon and Sumitomo as well as existing investors Pathfinder satellites, payloads and software developed, tested and integrated ahead of successful launch in December 2018 Successful launch of first cluster of three small satellites (December 2018) Ground infrastructure for relay of data/analytics to end-customers is operational, with software complete and awaiting deployment Introduce maritime domain awareness (MDA) products and realise commercial revenue Backlog build 	<ul style="list-style-type: none"> Following its Pathfinder mission, the initial three satellites were successfully commissioned in February 2019. Commercial and operational targets achieved

Source: Allied Minds

BridgeSat (2015)

BridgeSat is developing an optical communications service for data transfer from low earth orbit (LEO) and Geostationary Equatorial Orbit (GEO) satellites to earth (and vice versa), between satellites, between airborne platforms such as drones, and between points on the ground, targeting significantly lower-cost and faster rates than current radio frequency solutions.

Funding round (September 2018) and latest OAV (\$25.2m)

In May 2017, BridgeSat completed a \$6m Series A funding round, including participation from Space Angels, an early-stage investment group comprising experts in the Space 2.0 field. The fund-raise was completed at a pre-money valuation of \$15m (vs the previous valuation of \$7m).

In September 2018, Allied Minds contributed \$5m to a \$10m Series B round, which was led by Boeing. The fund-raise was completed at a pre-money valuation of c \$25m in line with the post-money valuation of the previous round. Allied Minds now holds 81.38% of the company.

Exhibit 8: BridgeSat milestones and objectives

H1 2018 milestone progress update	Edison commentary
<ul style="list-style-type: none"> \$10m Series B (September 2018), led by Boeing, with which the company is forming a broader partnership across several Boeing companies. Successfully demonstrate end-to-end service: network operations center (NOC), at least one ground station and customer pathfinder Sign 2+ customer agreements: Build strong commercial revenue backlog First ground station completed 2018 Backlog 6 patent filings 	<ul style="list-style-type: none"> Contracted with launch customers (three Pathfinder customers signed and one space terminal delivered) Signed agreement with Tesat to develop interoperability with BridgeSat's ground station network Contract award in Japan to deliver GEO space terminal for the ETS-IX GEO satellite programme (delivery in 2019) Signed ground station partnership with Swedish Space Corporation (SSC) Targeting, in total, 10 fully operational ground stations

Source: Allied Minds

Federated Wireless (2012)

Federated Wireless plans to offer a cloud-based SaaS service that unlocks spectrum previously unavailable to commercial users by enabling government and commercial users to securely share the same spectrum band. The partnerships with and investment by Charter Communications, Arris International and American Tower provide an encouraging endorsement and we would anticipate further operational newsflow in due course.

Funding round (September 2017) and latest OAV (\$63.5m)

In September 2017, Federated Wireless completed a Series B funding round raising \$42.0m. Strategic and financial investors were Charter Communications, American Tower and Arris International. Alongside Woodford, Allied Minds contributed \$9.0m for 5.82m Series B preferred shares. The transaction was completed at a pre-money valuation of \$79.5m (\$121.5m post money) and Allied Minds holds a 52.26% equity interest.

Exhibit 9: Federated Wireless milestones and objectives

H1 2018 milestone progress update	Edison commentary
<ul style="list-style-type: none"> Application to Federal Communications Commission (FCC) under initial commercial development: 15 end-user partners across 16,000 sites nationwide Environmental sensing capability (ESC) roll-out to complete Q119 Build out national ESC network Commercial agreements with Telrad, a leading US mobile network operator and Blinq Support multiple customer launches and realise commercial revenue 	<ul style="list-style-type: none"> FCC certification outstanding SAS commercial launch anticipated in 2019 Widespread service launch by mobile operators anticipated H219 Evidence of the pace of commercial deployment anticipated end 2019

Source: Allied Minds

Precision Biopsy (2008)

Precision Biopsy is a medical device and analytics company that uses spectral analysis to distinguish tissue characteristics in real time, with the aim of improving diagnostics and therapies. Initially focused on prostate cancer (PC), the technology is potentially applicable to other cancers.

Funding round (February 2019) and latest OAV (\$52m)

In its latest funding round, announced on 7 February 2019, Allied Minds and Woodford Investment Management agreed to jointly provide convertible bridge finance of \$5m to Precision Biopsy, intended to bridge to the next round to fund its pivotal SCORE study.

At H118 results, Allied Minds indicated that the OAV of Precision Biopsy had been reduced due to the delay in the Cohort B pivotal trial, now expected in 2019. We estimate a new OAV of c \$52m, a reduction from our estimate for Allied Minds' equity value of \$62m (for 65% of the equity) at the time of the previous fund-raise in October 2016.

Exhibit 10: Precision Biopsy milestones and objectives

H1 2018 milestone progress update	Edison commentary
<ul style="list-style-type: none"> Improved algorithm accuracy – supports biopsy, 3D mapping and focal therapy Cohort B IDE submission completed Prompted further work on data and algorithm 3D mapping prototype developed, ready for first-in-man studies Gain CE mark 	<ul style="list-style-type: none"> \$5m bridge financing provided by Allied Minds/Woodford Further strategic round required to facilitate full Cohort B study in 2019 FiM studies for 3D mapping dependent on further financing

Source: Allied Minds

SciFluor Life Sciences (2010)

SciFluor Life Sciences is a drug development company focused on creating a portfolio of best-in-class compounds in the field of ophthalmology. Lead clinical asset SF0166 is a topical eye droplet treatment for retinal diseases including neovascular age-related macular degeneration (wet AMD) and diabetic macular edema (DME). In April 2018, SciFluor appointed Bob Dempsey to its board. He brings 25 years of experience in ophthalmology and is leading the global ophthalmology franchise at Shire.

Funding round (February 2019) and latest OAV (\$63m)

In its latest funding round, announced on 7 February 2019, Allied Minds and Woodford Investment Management agreed to jointly provide convertible bridge finance of \$4m to SciFluor, intended to bridge to a Series B round to fund Phase II trials for its SF0166 topical eye drop treatment for retinal disease as well as position the company for the growth of its platform.

At the H118 results, Allied Minds indicated that the OAV of SciFluor had been reduced due to the adverse effect on the company's clinical and regulatory plans following the delay in planned financial activities during 2018. We estimate a new OAV of c \$63m, a reduction from the valuation established in the April 2015 round, when the total valuation of SciFluor increased from \$37.1m to \$130.7m (post money) and Allied Minds' 69.94% holding in SciFluor increased by \$60.6m to \$91.4m.

Exhibit 11: SciFluor Life Sciences milestones and objectives**H1 2018 milestone progress update**

- Bob Dempsey appointed to board
- SF0166 tox study to support longer-term dosing ongoing

Edison commentary

- \$4m bridge financing from Allied Minds/Woodford Investment Management
- Further strategic round required to initiate Phase II trial/s for SF0166
- Ongoing SF0166 tox studies funded by recent bridge financing

Source: Allied Minds

Spin Memory

Analysts: Anne Margaret Crow, Dan Ridsdale

Exhibit 12: Investment summary

Subsidiary	ALM % holding	OAV* (\$m)	Co-investors	Addressable market**	Recent funding rounds
Spin Memory (2007)	41%***	\$72m	Woodford; Invesco; NYU	Next generation MRAM semiconductor memory. Estimated \$20bn total addressable market.	\$52m Series B funding round led by Applied Ventures and Arm announced November 2018

Source: Company accounts. Note: *Edison estimates based on previous funding rounds as well as recently updated group OAV and group accounts. **Allied Minds estimated addressable markets for its products. ***Allied Minds anticipates holding 40.88% of Spin Memory's equity post second closing of the latest November 2018 investment round.

Overview

Spin Memory was established in 2007 by Allied Minds and New York University to develop and commercialise techniques that address the performance issues of MRAM. MRAM is an emerging memory technology that is expected to make significant inroads into the \$60bn+ (and growing) DRAM and SRAM memory markets. MRAM's advantages derive, in part, from its non-volatile and lower power consumption characteristics, increasingly important as data intensive (high power consumption) applications proliferate. Key industry players such as Global Foundries, Samsung, Sony, TSMC and UMC are investing in developing the technology and production capacity. However, the market is still at an early stage of development and key bottlenecks in terms of improving the endurance, improving the speed and reducing the size/footprint still need to be resolved to enable broader adoption.

Spin Memory has developed a portfolio of technologies, Endurance Engine, the Spin Polarizer and 3D and multi-layer implementation methods, which help address the bottlenecks. Management intends to commercialise the technology by initially licensing it to silicon foundries and integrated device manufacturers. When all the technology components are in place, the company may also pursue a fabless business model, designing and selling its own chips but outsourcing manufacture. The near-term opportunity looks strongest in licensing Spin Memory's IP into applications currently served by embedded SRAM (ie where SRAM memory is included on a system on chip), where embedded Spin Memory-MRAM (spin transfer torque MRAM) gives significant die-size reduction and thus potential for cost reduction. Management estimates the addressable market for its IP is \$500m. The recent commercial agreements with Applied Materials and Arm confirm this view. Further out, management is targeting the much larger DRAM market with a combination of all three of its key technologies, pursuing a licensing and fabless chip model. The DRAM market is worth c \$50bn annually, of which management estimates \$20bn (total semiconductor and IP value) could become addressable to Spin Memory. The company intends to have a solution for this market ready by 2021.

In November the group announced that Spin Memory had completed a \$52m Series B funding round led by the venture capital arm of Applied Materials and Arm. There are two commercial agreements associated with this funding. In the first, Spin Memory is to work with Applied Materials to create a comprehensive embedded MRAM solution that brings together Applied Materials' deposition and etch capabilities and Spin Memory's Spin Polarizer process IP. The second is with Arm to license Spin Memory's Endurance Engine design IP in SRAM applications in SOCs (system-on-chips). Allied Minds stated that the pre-money valuation of the round was at the same level as that used for the OAV calculation in the company's H118 results. However, the deal will likely provide future benefits through the commercial agreements with Applied Materials and Arm and so represents a significant milestone in terms of validating the company's potential to grow into this sizeable market opportunity.

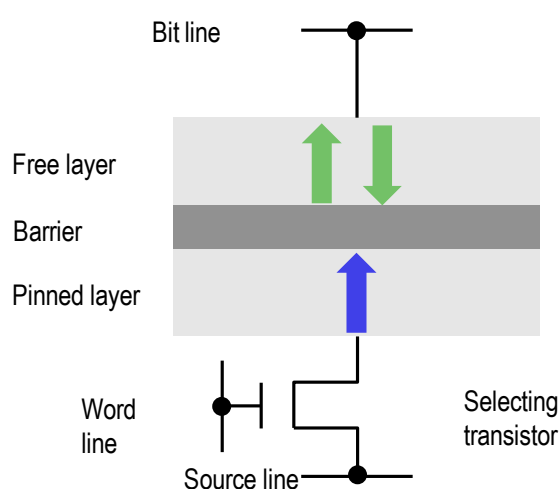
Exhibit 13: Spin Memory milestones and objectives

2018 milestone objectives	Edison commentary
<ul style="list-style-type: none"> Spin Polarizer demonstrated 40–70% efficiency gains Endurance Engine shown to increase endurance by up to six orders of magnitude, in line with DRAM Syndication of \$22.8m bridge underwritten by Allied Minds (October 2017). \$10.3m convertible bridge facility with existing shareholders (January 2018) Demonstrate Spin Polarizer and Endurance Engine benefits Broaden and deepen licensee base 	<ul style="list-style-type: none"> Completion of \$52m Series B fund-raising led by Applied Ventures and Arm Commercial agreements signed in parallel with Applied Materials and Arm Operational targets achieved John Kispert added as Chair

Source: Allied Minds

Technology overview

MRAM is a non-volatile random-access memory technology that uses magnetic charges for storing data instead of electric charges as in the case of DRAM and SRAM technologies.

Exhibit 14: Diagram of Spin Memory-RAM structure


Source: Edison Investment Research

MRAM cells are based on a perpendicular magnetic tunnel junction (pMTJ) structure. This is a sandwich of two layers of ferro-magnetic material separated by a very thin layer of dielectric magnesium oxide material. This has been widely used as a material in read-heads for disk drives for many years. The direction of the magnetisation of one of the ferro-magnets is changed, while the direction of the other ferro-magnet is fixed. When the two ferro-magnets are magnetised in the same direction, electrons can tunnel more easily through the insulator, putting the junction into a low resistance state. When they are magnetised in opposite directions electrons have more difficulty tunnelling through the insulator, putting the junction into a high resistive state. The low resistive state represents a '1' being stored. The high resistive state represents a '0' being stored.

Most MRAM switches the magnetic state of the non-fixed ferro-magnet, thus programming or writing an individual bit of the memory array, by manipulating the spin of electrons with a polarising current. This technique provides a significant reduction in switching energy compared to earlier forms of MRAM. MRAM deploying the technique is referred to as spin-transfer torque MRAM (Spin Memory-MRAM).

Market context

The global memory chip market was estimated to be worth \$130bn in FY17, representing c 30% of the total semiconductor market by value. Within this the DRAM and NAND memory markets are the two largest segments, worth an estimated \$73bn and \$49bn, respectively, according to Gartner. We highlight the key memory types, with their characteristics in Exhibit 15.

As with other semiconductor types, the development of innovative memory technologies is crucial to enabling new markets to develop and existing ones to continue to evolve. In particular, MRAM is seen as a potential solution for key bottlenecks in incumbent memory technologies, such as a flattening scalability curve, and power consumption. If left unaddressed these bottlenecks could hold back advances in areas such as Artificial Intelligence (AI), mobile computing and the Internet of Things (IoT) as well as addressing the spiralling problem of datacentre power usage.

The market opportunity for MRAM is seen as first within applications serviced by embedded SRAM. SRAM is high-speed expensive memory used in applications such as cache for memory chips or as part of the random-access memory for a video card, which demand the high speeds SRAM is capable of. The market for standalone SRAM chips is relatively small (estimated market size approximately \$400m); however, it is widely used as a component on processor system on chip (SoC) designs.

Looking further forward, enhancements to MRAM to reduce its cell size and power consumption have the potential to open up elements of the much larger DRAM market. DRAM accounted for over half the industry's revenues in 2017 (the market is famously cyclical) and is used for storage in datacentres, computers and networking infrastructure.

At present we believe the potential for MRAM in the non-volatile market segment is relatively small compared to the SRAM and DRAM segments, as these markets are well served by incumbent flash technologies. Management estimates it is worth \$250m annually, although Everspin estimates that the MRAM opportunity with regards to solid-state drives (SSD) and redundant array of independent disks (RAID) systems is \$1bn.

Exhibit 15: Comparison of existing memory types

Property	DRAM	SRAM	NOR flash	NAND flash	MRAM (current)	Potential Spin Memory MRAM enhancement
Estimated market size	\$72.8bn	N/A \$0.4bn for discrete chips but typically embedded into SoC designs.	\$1.67bn	\$32bn	Emerging	
Main applications	Data centres, PC, comms	Comms, embedded industrial, auto	Computing, mobile, consumer	Computing, mobile, consumer	Initially as SRAM, moving into DRAM and Flash	
Write speed (nsec)	High (10+)	Very high (5–10)	Low (1,000)	Medium (500)	Medium 40	Competitive >20 with Spin Polarizer
Cell size(F ²)	Small (6–10)	Very high (150)	Quite small (10)	Very small (4)	Small (6-12)	Potential to match DRAM with 3D Multilayer
Endurance (number of switches before failure)	High (10 ¹⁵)	High (10 ¹⁵)	Low (10 ⁵)	Low (10 ⁵)	Medium (10 ⁸)	10 ¹⁴ with Endurance Engine
Power consumption (Write)	Low	Very low	Very high	Moderate	High	
Other power consumption	Refresh current	Current leakage	None	None	None	Significant improvements with Spin Polarizer
Non-volatile	No	No	Yes	Yes	Yes	
Suppliers	Samsung, Micron, SK Hynix	Qualcomm, Intel	Cypress, GigaDevice, Macronix, Micron, Winbond	Samsung, Toshiba, SanDisk/WD, Micron, SK Hynix, Intel	Everspin	

Source: Company data, IC Insights, Technavio, Yole Developpement, World Semiconductor Trade Statistics

Low endurance and high cell size are limiting MRAM uptake at present

The utopian view of MRAM is that, by combining the inherent advantages of both DRAM in terms of density and SRAM in terms of read and write speed, the technology has the potential to become a universal memory in the coming years, taking a significant share of the SRAM and DRAM markets and flash memory applications where high write endurance is required.

In reality, however, MRAM's ability to displace either of these memory technologies has been limited by the time it takes to change (write) the data held in an individual memory cell, the amount of power required to change the state of the non-fixed ferro-magnet, the size of each memory cell and the number of times the '0' or '1' stored in that memory cell can be changed before the cell begins to degrade (endurance).

These performance limitations mean that MRAM is only used in niche applications where a non-volatile form of memory is required:

Flash memory substitute in computing chips: Computing chips often have some embedded flash memory to store code when the power is off. MRAM already has better speed and endurance than flash memory. Moreover, NOR flash is difficult to scale beyond 28nm, suffering from slow write speeds and endurance issues and becoming more expensive as more mask steps are required.

Write-cache in SSDs: Everspin, the leading independent MRAM chip vendor, is also targeting its STT-MRAM for write-cache applications in SSDs and RAID systems. Typically, SSDs use a DRAM-based buffer to help speed up the system. If the system loses power, the data are at risk so SSDs incorporate capacitors, adding cost to the system. Together with its partner, SMART Modular Technologies, Everspin has begun to ship its nvNITRO accelerator card, which uses STT-MRAM in the write-buffer socket of the SSD.

Spin Memory's technology potentially solves MRAM problems

Spin Memory is developing technologies that potentially solve the issues of speed, power consumption, size and endurance, enabling MRAM to become a viable alternative to SRAM and eventually for DRAM. Spin Memory has more than 150 patents issued or pending in relation to these three technologies.

Spin Memory's proprietary technologies include:

- **The Endurance Engine**, which is actually complementary metal oxide semiconductor (CMOS) control circuitry that improves MRAM endurance by up to six orders of magnitude by optimising the operating voltage of the pMTJs. This raises endurance from 10^8 cycles to 10^{14} cycles. While this is not the same level of endurance as DRAM, it is equivalent to five to 10 years at GHz clock speeds, which is perfectly adequate for almost all applications. The Engine also results in smaller write currents (lower power consumption) and smaller base transistors, enabling scaling. Since the Engine requires no changes to the pMTJ, it may be licensed to improve the performance of third-party pMTJs.
- A proprietary, patented **Precessional Spin Current Structure** or **Spin Polarizer**, which is a series of magnetic polarising materials that can be layered on top of a pMTJ. This has been shown to improve efficiency, defined as the energy barrier to switching (changing the '0' or '1' stored in the memory cell) divided by the current required for switching, by 40–70%. Prior to this invention, increasing the energy barrier in an attempt to improve data retention inevitably resulted in a proportional increase in write current leading to higher power consumption and much faster wear-out of the pMTJ (ie lower endurance). These two effects are now decoupled, making it possible to create MRAMs that can hold data for over 10,000 times longer without negatively affecting switching current or endurance. The efficiency gain has been demonstrated for 40–60nm devices across a 30°C to 125°C temperature range, the higher temperatures being suitable for automotive applications. Since efficiency gains increase as the pMTJ gets smaller, the technique opens new pathways to achieving embedded SRAMs in 7nm and 5nm nodes. As the Spin Polarizer technique adds minimal complexity (another 4nm to the height of the cell stack) or cost for foundries it may be licensed to improve the performance of its customers' pMTJs.
- **3D multi-layer architecture**: a 3D multi-level cell structure that enables increases in densities to a level that, when combined with the Spin Polarizer and Endurance Engine, will allow MRAM

to match or exceed the characteristics of DRAM. This high-density approach is being developed by the advanced technology group within the company.

Importantly, the technologies are scalable for smaller process nodes enabling them to keep track with the evolution of the semiconductor market. The technology is also compatible with existing CMOS fabrication processes that have been adapted to accommodate MRAM cells. The pMTJs sit between two metal layers and require around three additional masks. There is already an ecosystem for manufacturing Spin Memory-RAM on 300nm wafers at less than 40nm, with GlobalFoundries, Samsung, Sony, TSpin MemoryC and UMC offering or working on MRAM-compatible processes.

In 2015, Spin Memory built a complete back-end magnetics R&D fab at its headquarters in California. This enables it to manufacture a new variant of the technology, with device features as small as 10nm in 10 days. This is a significant competitive advantage because it typically takes 50–100 iterations to bring a memory technology to commercial readiness.

Step one: Embedded SRAM replacement; \$500m TAM from 2019

Spin Memory's initial commercial focus is on the SRAM market, the preferred storage technology for cache memory where data and instructions that are very frequently accessed and written are held. SRAM's six transistor structure switches from one data state to another quickly, but also requires more space than DRAM, which has only one transistor per memory cell. The opportunity here is to replace some or all of the embedded SRAM with embedded Spin Memory-MRAM to achieve a significant die-size reduction and thus potential to reduce cost.

A solution for memory bloat

This issue of memory bloat is particularly serious. This is because the SRAM memory architecture is difficult to scale down in size as the transistors on silicon chips transition to smaller and smaller dimensions. As a consequence, memory is taking up a greater proportion of the chip real estate, significantly driving up cost. In a modern system on chip, central processing unit or graphical processing unit, 50–80% of the chip area is taken up by memory. At the International Solid State Circuits Conference in 2014, Cypress Semiconductors gave a presentation noting that in transitioning from a 28nm process node to 16nm density in a large SRAM block, which theoretically should give a four times improvement in density, the actual improvement was only 1.6x for designs operating at a low processing speed (c 500MHz) and only 1.1x at a good processing speed (1,500MHz). The presentation reviewed the feasibility of shifting to a 16nm node to create a more powerful telecommunications interface chip (a 400G line card). It concluded that while the extra logic transistors could be accommodated, the SRAM would become so big that the chip size would exceed the limits of what can be made using existing semiconductor equipment.

Moreover, since Spin Memory-MRAM is non-volatile and retains the data stored when there is an accidental power outage or the device is deliberately turned off, replacing SRAM with Spin Memory-MRAM presents the possibility of adding new functionality, such as rapid boot times for mobile and storage devices. Management notes that adding Spin Memory's Endurance Engine to existing MRAM designs will result in chips with sufficiently improved switching times, power consumption and endurance to be a viable substitute for embedded SRAM.

In 2019 the company aims to start addressing this market, which it estimates is worth \$500m annually, by licensing IP to foundries and integrated device manufacturers.

The big prize: Persistent DRAM; \$20bn market from 2021

Spin Memory believes the combination of its three technologies (Endurance Engine, Spin Polarizer and 3D multi-layer architecture) give it the potential disrupt the high-end DRAM market, through achieving DRAM levels of speed and endurance but dramatically lowering power consumption. DRAM is used across a very wide range of devices with a total market size management estimates

to be worth over \$70bn. Spin Memory is targeting the high-performance segment of the market, which it estimates could be worth \$20bn. We note that Everspin estimates that the potential for replacement is smaller (\$4.8bn), which may be because it is not factoring in the benefits of Spin Memory's IP.

DRAM is a very fast, compact and long-lasting memory technology that uses a single transistor to store charge (equivalent to storing a '1' in the memory cell). However, as it is volatile, keeping the charge topped up requires a lot of power. This is a big problem for datacentre owners with regards to cost (energy represents around one-quarter of datacentre costs) and environmental impact. It also has implications for the future growth in datacentres. In 2017, Forbes Technology Council noted that US datacentres use more than 90bn kWh of electricity a year, equivalent to 34 giant (500 megawatt) coal-powered plants. Globally, datacentres used roughly 4.16×10^{14} watts in 2016 (equivalent to 3% of the total electricity consumed) and nearly 40% more than the entire UK. Forbes estimates that a doubling in the number of IoT devices between 2016 and 2020, together with a rise in AI applications analysing this data, will require a doubling in datacentre processing capability and notes that expanding global electricity production to accommodate this will not be feasible unless computer architecture changes. Additionally, scaling DRAM below 10nm is extremely challenging.

Penetrating this market will be more of a challenge than SRAM because the company's three proprietary technologies (the Endurance Engine, the Spin Polarizer and 3D and multi-layer implementation methods) are required to deliver the promised power reduction in a competitively sized chip. Nevertheless, due to the much larger size of the DRAM market and because licensees will need to deploy more of Spin Memory's IP, the opportunity in DRAM is significantly larger than for SRAM. Structurally, the DRAM market is very different from SRAM in that DRAM memory is mainly sold in a discrete chip, whereas SRAM is mainly embedded in SoC solutions. This means that it is much more viable for Spin Memory to pursue a fabless chip supplier model in this market as well as, or instead of, IP licensing. Penetrating this market is key if Spin Memory is to deliver on its promise of evolving into a high-growth, high-margin IP licensing business.

Market landscape

The extent of investment into MRAM technologies across the semiconductor industry gives a good indication that this is a technology with significant potential. Several semiconductor foundries are able to fabricate discrete and embedded MRAM (see Exhibit 16). At least one company, Everspin, is already shipping MRAM devices in commercial volumes. Other major players are developing devices and should be considered potential users of Spin Memory's IP rather than competitors.

Exhibit 16: MRAM market participants

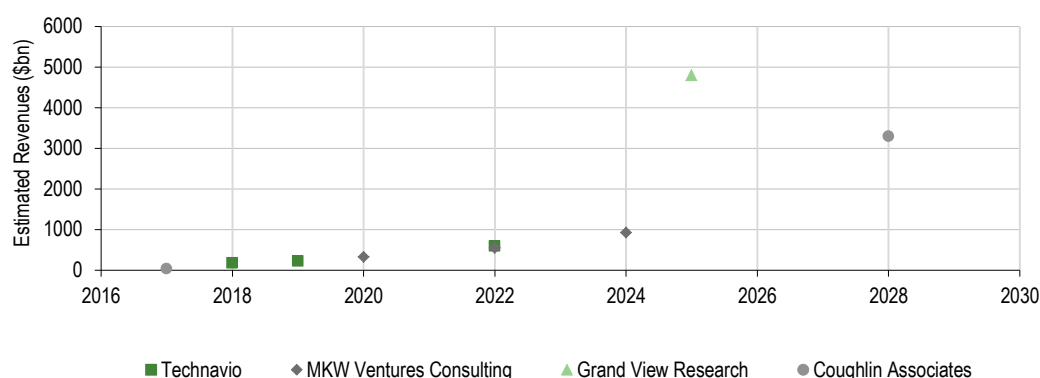
Company	MRAM capability
Avalanche Technology	Sampling discrete parts up to 64Mb, was originally intending to ramp to production in 2017 but not in production yet
Crocus Technology	Primarily applying MRAM technology to development of magnetic sensors. In 2011 formed a JV called Crocus Nano Electronics with Russian Nanotechnology Corp to build an MRAM fab in Moscow, Russia. In January 2018 the JV announced successful test results for its 90nm pMTJ STT-MRAM technology. It expected to produce its first engineering samples by the end of 2018
Everspin	Spin-out from Freescale Semiconductor, which was originally a spin-out from Motorola. Since 2014 it has shipped 70m MRAM chips including a 256MB Spin Memory-MRAM, based on a 40nm process from its foundry partner, GlobalFoundries. It is sampling a 1GB chip based on GlobalFoundries' 28nm process. It also offers embedded MRAM. The technology has been licensed by Cobham. MRAM has limited endurance (10^9) and is relatively slow (35nsec access time). Is selling embedded MRAM to NXP
GlobalFoundries	Launched embedded MRAM on its 22nm fully depleted silicon-on-insulator platform in 2016. Development in partnership with Everspin. Demonstrated Spin Memory-MRAM technology in a 40-Mbit array with 10 years of data retention at 125° Celsius and extended endurance of about 10^7 cycles, demonstrating applicability for automotive applications. Over time, the foundry plans to develop embedded MRAM for its 12nm FD-SOI process as well as 14nm and 7nm finFETs
Honeywell International	Offers MRAM < 64MB for space applications
IBM	Working on Spin Memory-MRAM material technology with Samsung
NVE Corporation	Primarily involved in the manufacture of spintronics sensors and couplers. Has licensed MRAM IP to Motorola, Honeywell and Cypress Semiconductor
NXP	Working with Samsung on MRAM as a replacement for embedded flash
Samsung	Acquired MRAM developer Grandis in 2011. Announced that foundry customers can have embedded MRAM in their 28nm FD-SOI SoCs. Taped out a 28nm FD-SOI MRAM in 2017 and is preparing to use eMRAM as a core for SoCs. Technology was developed with IBM and Infineon and its first use will be in an NXP i.MX processor. Volume production was scheduled for 2018
SK Hynix Semiconductor	In partnership with Toshiba, presented prototype 4GB Spin Memory-MRAM in 2016 with cell density only slightly less than DRAM
Sony	Using 300mm diameter standard CMOS wafers for work with Avalanche
TDK Headway Technologies	Specialists in MRAM recording head technology. Has presented 8MB test chips using IBM's 90nm CMOS process
Toshiba	Partnering with SK Hynix
TSTTC	Announced plans to start offering embedded MRAM in 2018 and embedded RRAM in 2019 on its 22nm finfet process node. Working with TDK-Headway
UMC	Announced plans to offer MRAM compatible process

Source: Edison Investment Research

Sizing the market

It is important to make the distinction between the total addressable market for MRAM and the forecast market size, which is inevitably smaller. So, while Spin Memory estimates that its total addressable market will reach close to \$20bn by 2021, MRAM will likely only capture a percentage of this in this timescale. Moreover, Spin Memory's estimate of a \$500m total addressable market (TAM) in SRAM is for the company's IP, which would be close to 100% gross margin, whereas the \$20bn estimated TAM for DRAM is for chips – so higher value but substantially lower gross margin. Estimating the TAM for Spin Memory's IP in the DRAM replacement market is a very imprecise exercise but, depending on how complete an IP solution Spin Memory has for creating memory chips, we estimate it could be somewhere between \$400m and \$1.2bn (2% and 6% of the chip TAM).

Looking across a spread of market analysts' forecasts for total MRAM revenues indicates a central scenario of growth towards a \$1bn market in the 2024 timescale, followed with a potential inflection after that.

Exhibit 17: Market analysts – MRAM revenue forecasts


Source: Various sources as identified in legend

Trends underpinning this growth are:

- AI chips need to hold the data close to where they are processed but the sheer volume of data, combined with the limitations of continuing to scale SRAM at smaller dimensions, means that the development of more powerful AI chips is constrained by how much memory can be included on-chip. Replacing some or all of the SRAM with MRAM potentially removes these limitations.
- Emerging AR/VR and IoT applications need non-volatile alternatives to SRAM and DRAM so they can retain information without draining the battery, but without the low write speeds and poor endurance of flash memory. Considering the increasing number of sensors in automobiles to support autonomous driving, any MRAM solution needs to be able to perform in the elevated temperatures experienced in automobiles. The Spin Polarizer structure has been shown to support a much higher operational temperature than older STT-MRAM techniques.
- Data centres may potentially migrate to MRAM, thus delivering higher performance while consuming less electrical power.

Management team and background

Of the c 60 people Spin Memory employs, around one-third hold PhDs. The engineering team includes experts across a wide range of disciplines, deflecting the disruptive nature of the architecture, with strengths in both magnetics and CMOS memory technologies. This unusual combination enables it to consider improvements in materials and memory design in a holistic manner that is more effective than optimising either aspect individually.

Key leadership includes:

John Kispert, chairman: appointed to this role in September 2018, John was previously CEO of Spansion, where he identified new, wider target markets and radically repositioned core products; launched over 50 new product platforms over a five-year period; drove company valuation through organic and acquisition growth; and licensed IP for over \$200m. Before that, Kispert spent 13 years at KLA-Tencor, including as president, COO and CFO, and helped transform the semiconductor equipment company from \$300m to over \$3bn in annual revenues.

Tom Sparkman, chief executive officer: appointed CEO in July 2017. He has nearly 36 years of experience across medical, automotive, semiconductor and wireless technologies. He was previously CEO of Samplify Systems, a start-up developing mixed-signal semiconductor and ultrasound solutions, where he raised over \$25m in capital. He also worked for 19 years at Maxim Integrated Products, held general manager and senior vice president (VP) of worldwide sales roles at Integrated Device Technology, and was general manager and senior VP, worldwide sales at Spansion, prior to its merger with Cypress Semiconductor.

Dr Andrew Walker, VP product: Dr Walker has more than 30 years of experience in the semiconductor industry. Since 2000 he has focused on 3D flash memory, founding Schiltron Corporation to develop new 3D memory technology. He has worked for Cypress Semiconductor, Artisan Components and Matrix Semiconductor. Between 1985 and 1994 he worked at Philips Research Laboratories on CMOS and non-volatile memory research and development. He was appointed in October 2017.

Dr Mustafa Pinarbasi, CTO and senior VP of Magnetics Technology: Dr Pinarbasi is a pioneer and innovator in magnetic thin films. He spent the first 18 years of his career at IBM and Hitachi Global Storage Technologies developing magnetic materials and thin films. For example, he pioneered the adoption of ion beam sputtering deposition technology by the magnetic head industry, worked on the giant magnetoresistive (GMR) sensors used in the first GMR-based hard disk drives and led the development of tunnelling magneto-resistance read-head processing used in hard disk drive products. Prior to joining Spin Memory, he was CTO at SoloPower, a thin film solar company, where he built a comprehensive technology team, developed roll-to-roll thin film photovoltaic deposition processes and equipment, and spearheaded the industry's first flexible and lightweight CIGS (copper indium gallium di-selenide)-based solar modules. He was appointed in February 2013.

Dr Amitay Levi, VP memory integration: Dr Levi has more than 28 years' semiconductor industry experience in advanced technology development of non-volatile memory. He spent several years at Crocus Technology as VP technology development, working on MRAM technology. Before that he was VP of Embedded Technology at Silicon Storage Technology where he was responsible for supporting technology licensing and developing Embedded SuperFlash and VP Advanced Development, where he led a group developing SuperFlash technology for standalone chip products.

Les Crudele, senior VP IC product development: Les Crudele has over 40 years of proven leadership and business management experience related to integrated circuit development and large-scale systems. His career includes being VP and general manager of Motorola Semiconductor's PowerPC RISC Microprocessor Division, VP and general manager of Compaq's Workstation Products Division and CEO of Banderacom, Transmeta and Azuray Technologies. He was appointed in July 2016.

Jeff Lewis, senior VP of business development: Jeff Lewis has extensive experience in the semiconductor IP and electronic design automation industries, focusing on licensing technologies in the memory sector. Most recently, he was senior VP of business development and marketing at SuVolta, where he directed the company's licensing and customer and market engagement activities, including their strategic partnership and ultimate acquisition by Fujitsu. Prior to that, he was senior VP of business development and marketing at Innovative Silicon. He was also president and CEO of CiraNova, an EDA software company acquired by Synopsys, and held VP positions at FormFactor, Artisan Components and Compass Design Automation. He was appointed in July 2016.

History to date

Following the appointment of Tom Sparkman as CEO in July 2017, short-term goals were changed to reflect an increased focus on commercial exploitation of the technology.

Exhibit 18: Significant milestones

Date	Achievement
2007	Formation of Spin Memory by Allied Minds and New York University
July 2014	First phase of integration of magnetic and CMOS wafer technology completed
October 2014	\$70m raised
February 2016	Production of a working prototype device. Announcement of a co-development agreement with a major memory company
2016	Becomes only the second company to have shipped perpendicular STT-MRAM samples. Fabricates key magnetic components at 20nm node, which is among the smallest MTJs ever reported. Completes prototypes of memory arrays at megabit level densities
July 2017	Appointment of Tom Sparkman as CEO
October 2017	Partnership announced with Tokyo Electron to improve speed, density, and endurance of STT-MRAM devices by combining Spin Memory's pMTJ design and device fabrication technology and TEL's PVD MRAM deposition tool and experience of creating magnetic films to develop processes for high density and endurance devices. Spin Memory and TEL intend to demonstrate solutions that are 40–50% smaller than other commercial solutions which would be a significant step toward making DRAM-class STT-MRAM devices
October 2017	\$22.8m convertible bridge facility to fund Spin Memory through to completion of Series B funding round secured
2017	Create 1GB of data to demonstrate advanced pMTJ capability. Held over 50 partner meetings. 87 new patents filed
January 2018	Syndicated \$10.3m of \$22.8m convertible bridge facility underwritten by Allied Minds in October 2017
Q118	Emulator demo and FPGA demo of Endurance Engine demonstrated
April 2018	40–70% improvement in pMTJ efficiency through use of the Spin Polarizer announced
November 2018	Completion of \$52m Series B fundraise and commercial agreements with Arm and Applied Materials. Commercial agreements and licensing agreements nearing completion. The first agreement pending is the grant of a licence to jointly develop the Endurance Engine technology for the embedded systems market. The second is a licence for combining the Spin Polarizer technology with another industry leader's magnetics technology to create magnetics turnkey solutions for licensing to foundries seeking an MRAM solution for the non-volatile and SRAM market segments. Both agreements include a competitive revenue share stake for Spin Memory from future sales, which management expects will commence in late 2019. In combination with each of the commercialisation agreements, Spin Memory has entered into a conditional term sheet for a financing round led by the two potential strategic partners.

Source: Edison Investment Research

Commercialisation path and key milestones

In November 2018, Spin Memory completed a \$52m Series B funding round led by the venture capital arm of Applied Materials and Arm. There are two commercial agreements associated with this funding. In the first, Spin Memory is to work with Applied Materials to create a comprehensive embedded MRAM solution that brings together Applied Materials' deposition and etch capabilities, Spin Memory's spin polarizer process IP and pMTJ technology from both companies. This is intended to allow chip fabrication facilities to quickly create their own lines for manufacturing embedded MRAM products for both non-volatile and SRAM-replacement applications. Spin Memory intends to make the solution commercially available from 2019. The second is with Arm to license Spin Memory's Endurance Engine design architecture to develop a new line of embedded MRAM IP. This will address SRAM applications in SOCs, with denser and lower power solutions than those typically achieved with the current six transistor SRAM architecture. Spin Memory is on the verge of completing a very major milestone, with the group having announced that Spin Memory is in the final stages of consummating licence and joint development agreements with two leading industry players. In parallel, Spin Memory has entered a conditional term sheet for a financing round led by the two potential strategic partners to provide necessary funding for the company.

The deal will likely provide future benefits through the commercial agreements with Applied Materials and Arm and so represents a significant milestone in terms of validating the company's potential to grow into this sizeable market opportunity.

Looking ahead, we see the key milestones for Spin Memory as being:

- Newsflow indicating that commercialisation through the two partners above is on track.
- Further expanding the licence base across the semiconductor industry – this is important for maximising the revenue potential and diversifying risk.
- Deepening the licensee base – securing licence wins for all three key technologies with key semiconductor players. This is important to maximise royalty potential per chip, but also as an indicator of the company's potential in the \$20bn high-end DRAM market.
- The first chip design wins and then starts – first in SRAM (2019/20) then DRAM (2021/22).
- The first commercial embedded MRAM manufacturing lines.

Valuation

Management has not provided any guidance on how revenues may develop. This will depend in part on whether Spin Memory adopts a business model where it sells standalone MRAM chips, or licenses IP for embedded MRAM or licenses its Endurance Engine or Spin Polarizer IP to improve the performance of MRAM technology offered by other vendors.

We note that Everspin reported revenues of \$35.9m in 2017 and consensus is estimating \$48.1m of revenues in 2018. Its market capitalisation of c \$149m represents 3.1x prospective revenues. Clearly, we need to factor in the time value of money and future fund-raising, but as a guide, applying the same ratio to Spin Memory's potential revenues from standalone chip sales, our estimated valuation of \$176m would indicate prospective revenues of c \$57m, which represents 0.3% of the \$20bn TAM DRAM substitution market. Given that there are already several other companies offering MRAM chips, we believe that licensing Endurance Engine and Spin Polarizer IP is more likely.

From an IP licensing perspective, the blue-sky scenario for Spin Memory is that the company succeeds in gaining broad adoption of its IP across the relevant memory markets, with its IP becoming an almost de-facto standard architecture across the industry, much as Arm did in microprocessors. There are very many milestones for the company to achieve for this to become a likely eventuality; if successful, the company should capture a good proportion of a TAM for IP across SRAM and DRAM, which could ultimately be worth between \$0.9m and \$2bn. In this scenario, margins should also be strong; for example, Arm achieved close to 50% margins before its acquisition by SoftBank, while Interdigital, which has a broad portfolio of mobile communications IP, registered 58% operating margins in FY17. Less ambitiously, we would look for the business to establish a broad licensee base and penetration of its partners to support sustainable growth and profitability. The margins of successful but non-dominant IP licensing businesses are significantly lower; for example the latest reported margins of Ceva were 18%. Achieving a good degree of diversity of royalty-generating licensees is essential for success sustaining robust financial performance and we would highlight the plight of Imagination Technologies, which fell into a loss on losing its dominant client, Apple, in 2016.

Looking to the valuation potential, visibility that the company is trending towards a de-facto standard IP position would indicate a blue-sky potential valuation well in excess of \$1bn. For example, Arm's EV/sales ratio averaged 10x in the three years prior to its acquisition (by Softbank at 24x). Interdigital is rated at 6.7x. The multiples of less dominant providers are understandably lower (eg Ceva 5.6x) but highlight that the intrinsic value of the IP does hold multiples up. For example, Imagination was sold for 3.7x trailing sales.

HawkEye 360

Analyst: Anne Margaret Crow

Exhibit 19: Investment summary

Subsidiary	ALM % holding	OAV* (\$m)	Co-investors	Addressable market**	Recent funding rounds
HawkEye 360 (2015)	48%	\$43m	Raytheon; Razor's Edge; Shield Capital; Woodford; Invesco; Sumitomo	Data analysis of radio frequency signals from its own satellite constellation and third parties for applications including maritime domain awareness. Estimated \$2.4bn market	\$14.9m series A-3 led by Raytheon (September 2018)

Source: Company accounts. Note: *Edison estimates based on previous funding rounds as well as recently updated group OAV.

**Allied Minds' estimated addressable markets for its products.

Overview

HawkEye is a data analytics company that aims to commercialise the capability to detect, independently geolocate and analyse diverse RF signals from space. It will use proprietary algorithms to combine RF signals detected by its own constellations of satellites with geospatial information to produce contextually relevant analytics and reports for government and commercial end-market applications. Its first cluster of three satellites was launched successfully in December 2018. The company was formed in 2015, is based in Herndon, Virginia, US, and employs around 30 people. Allied Minds holds a 48% stake.

Applications

Maritime domain awareness: this is the first market to be targeted by HawkEye. Maritime vessels engaged in illegal fishing, piracy, transshipments or smuggling may seek to evade detection by switching off their automatic identification system (AIS) and going 'dark'. HawkEye's capability may be used to detect other forms of RF emissions such as the radar from the 'dark' ship, making it possible to detect vessels that are attempting to hide or spoof their location and avoid interception. Importantly, the AI functionality embedded in the software can predict where a vessel may be going, which can be helpful if the RF signal disappears, and decide whether it is likely to be engaged in any illicit activity. Frost and Sullivan notes that (excluding defence and intelligence expenditure) this is a \$1.7bn market that it forecasts to grow to \$2.2bn by 2024.

Emergency response: HawkEye's ability to map spectrum utilisation before and after such natural disasters as hurricane landfalls will allow it to advise first responders and emergency government agencies on available communications mechanisms.

Search and rescue: HawkEye will be able to collect information from emergency locator beacons and independently locate them. This is important if the global positioning system (GPS) receiver embedded in a beacon is damaged or a victim is in a poor GPS reception environment, such as mountainous terrain.

Communications interference detection: HawkEye's spacecraft will be used to survey communication channels in a given area, protecting legitimate signals and helping to identify anomalies. A telecommunications provider that is actively affected by an interference issue could contact HawkEye for assistance in resolving the source of that interference. The data could potentially be used to inform future communications paths by analysing historical data and performance, enabling operators to avoid interference situations altogether.

Spectrum mapping and use: today's RF spectrum usage is dynamic. HawkEye is creating the first-ever global spectrum inventory and mapping processes that will have the ability to provide accurate and cost-effective utilisation data to government regulators.

Revenues from provision of data

HawkEye will derive recurring revenues from providing location and spectral data on RF signals to subscribers, from 2019 onwards. Management believes HawkEye is the only commercial entity planning to launch satellite clusters with precision detection of diverse RF signals, mapping and analytics capabilities, conferring first-mover advantages. As this is a new market, there are limited data available on its size. Management notes that, according to P&S Market Research, the commercial satellite imagery market is forecast to be worth \$6.9bn by 2023, indicating there is considerable potential value in commercialising other forms of space-based data collection and analytics. We note that DigitalGlobe, a global commercial provider of earth imagery and geospatial content that operates its own commercial remote sensing spacecraft, generated \$725.4m in revenues in 2016. It was acquired in February 2017 at an equity value of approximately \$2.4bn. Jill Smith, CEO of Allied Minds, was CEO of DigitalGlobe between 2005 and 2011, delivering a five-fold increase in revenue through market diversification and international expansion, growing the market capitalisation to more than \$1.5bn and taking the company public in 2009.

Technology overview

Hawkeye's system is formed of three core elements:

- **LEO satellite clusters:** HawkEye plans to operate up to 10 clusters of three LEO satellites. These will fly in formation, with two satellites a fixed distance apart and a third oscillating between them. This arrangement enables the satellites not only to detect RF signals, but also to accurately geolocate them without using a GPS or other third-party signal. The satellites are being constructed by third parties. Each satellite costs an estimated \$2–3m to construct, launch and insure. The satellite payloads will detect signals between 60MHz and 15GHz that are above 1W in power, which rules out detecting individual mobile phones. In the longer term, HawkEye will process data collected by other satellites.
- **Signals processing:** HawkEye uses open-source software from GNU Radio to process the multiple RF signal types.
- **Big data analytics products:** HawkEye uses its proprietary algorithms to combine RF data with other geospatial information to produce contextual analytic reports. This information may be accessed via a standalone platform, or integrated with other situational awareness data. Management is in discussions with Kongsberg Satellite Service regarding the incorporation of its geoanalytics products in Kongsberg's search and rescue division, particularly for marine surveillance. It is also working with Geospark Analytics to integrate HawkEye's maritime domain awareness and spectrum monitoring and mapping products into the latter's Hyperion platform. In May 2017 it announced a Memorandum of Understanding with Kratos Defense & Security Solutions to explore the potential of expanding Kratos's carrier monitoring, interference detection and geolocation offerings with HawkEye's RF detection and geolocation services.

Route to commercialisation

Exhibit 20: Significant milestones

Date	Achievement
September 2015	Formation
2016	Initial demonstrations using aircraft
2016	Series A fund-raising \$13.8m
February 2017	Completed the second closing of its \$13.8m Series A preferred funding round of \$1.3m, adding additional investors to a syndicate including Razor's Edge Ventures and a defence market leader
2017	Pathfinder satellites, payloads and software developed, tested and integrated on track for readiness ahead of Q418 launch schedule Demonstration of MDA capability using aircraft sensing RADAR, AIS and EPIRB signals Ground infrastructure for relay of data/analytics to end customers operational, with software complete and awaiting deployment
Q1-Q318	Development of commercial contract backlog ahead of Pathfinder launch, primarily with government agencies Expansion of advisory board
Q318	SEAKER maritime domain awareness product in beta-test using third-party data
September 2018	Completion of Series A-3 financing round raising \$14.9m in total. Led by Raytheon Company, the Series A-3 round included participation from the Sumitomo Corporation of Americas, Razor's Edge Ventures, Shield Capital Partners, Space Angels and Allied Minds. Proceeds will be used to fund the development, build and launch costs of the company's first commercial satellite cluster, which is scheduled for launch late 2019, and for general commercial purposes
December 2018	Successful launch of Pathfinder mission – its first cluster of three, formation-flying small satellites aboard Spaceflight's SmallSat Express rideshare on a SpaceX Falcon 9 rocket.
February 2019	HawkEye has successfully commissioned the Pathfinder satellites launched in December 2018 and, on the back of this important milestone, HawkEye will go to market with a full suite of commercially available RF analytics products over the course of 2019.

Source: Edison Investment Research

Next steps

Management's stated objective is to:

- Launch MDA products and realise commercial revenue by the end of 2018. Management expects the commercial version will be ready for when satellites start transmitting data in 2019. The first revenues have already been received from demonstrations and pre-sales of data subscriptions.

BridgeSat

Analyst: Anne Margaret Crow

Exhibit 21: Investment summary

Subsidiary	ALM % holding	OAV* (\$m)	Co-investors	Addressable market**	Recent funding rounds
BridgeSat (2015)	81%	\$28m	Boeing; Space Angels Network	Optical communications service for transferring data from satellites. Estimated \$1.5bn LEO sat-comms market	\$10m Series B round led by Boeing (September 2018)

Source: Company accounts. Note: *Edison estimates based on previous funding rounds as well as recently updated group OAV.

**Allied Minds estimated addressable markets for its products.

Overview

BridgeSat is developing a commercial optical communications service for data transfer from LEO and GEO satellites and airborne platforms down to and up from the Earth. This service will be based on free-space optical communications links that can provide data rates around 10 times faster than conventional microwave satellite downlinks. BridgeSat was founded in 2015. It is based in Denver, Colorado, and employs around a dozen people. Allied Minds' stake is 81%.

Free-space optical communications solves satellite data deficit

Free space optical communication is important because, according to *SatMagazine*, 27% of earth observation satellites already generate more data than they can downlink. The transmission deficit is expected to get worse as, according to research commissioned by management from Northern Sky Research, LEO satellite data downlink demand is expected to grow by over 125% pa through 2024 to c 1m terabytes. This growth is driven by a threefold increase in the number of satellites carrying a broader range of data-intensive sensors by 2022. The transmission deficit is significantly larger if the potential requirements of the large constellations of satellites, drones and balloons proposed for supplying broadband connectivity to remote areas are considered. Free-space optical communications are also more power efficient than microwave links, which is important for a satellite operating on solar power, and they are less susceptible to hacking and do not require a permit for operation.

Revenues from delivering downlink data

BridgeSat will derive revenues from service contracts for delivering downlink data, with fees varying according to the volume of data and service levels. It expects these to commence early in 2019. Its initial target market is the LEO data downlink segment, currently estimated to be worth \$1.5bn a year. In addition, it will target the GEO and inter-satellite data markets as well as platforms in the stratosphere, such as drones, balloons and commercial aircraft as well as ground-to-ground links. Management believes BridgeSat is the only commercial entity building a network of optical communications ground stations, conferring first-mover advantages. Airborne Wireless Network (ABWN:US) is proposing a network of around 500 ground stations to support its high-speed broadband airborne wireless network, but this has yet to be implemented.

Technology overview

BridgeSat is seeking to build an optical-based data delivery service that will enable data transfer to and from satellites and airborne platforms at speeds of up to 10Gbps and at significantly lower cost (up to 10x) than RF transmission on a dollar per byte basis at speeds above 1GBps.

BridgeSat's optical communications system has three core elements:

- **Space terminals installed on customer satellites.** The terminals are being designed in-house and manufactured by a third party. The first terminal, which will transmit at 1GBps and is for deployment on LEO earth observation satellites, weighs around 1.8kg and is the size of two

drinks cans. The cost of each unit has not been disclosed but management notes that the cost per MB transmission capability is a fraction of an equivalent RF terminal. Two units have been built so far. The first is already installed on a LEO satellite for tests. A second type of space terminal, which will transmit at 10GBps, is being developed for GEO applications in partnership with a Japanese customer. GEO terminals consume more power and require larger reflectors because GEOs are much further away from the Earth's surface than LEOs. BridgeSat is developing its own low-cost terminal to seed the market, although its intention is for the network to be able to transmit data from third-party terminals as well. We note that Ball Aerospace, Mynaric, Space Micro, Tesat-Spacecom and Thales Alenia Space Switzerland are developing space terminals.

- **Network of optical ground stations:** these are designed in-house using standard sub-systems. They include IP for alerting satellites to potential issues with transmission caused by weather conditions. The IP is licensed from the Draper Laboratory, which is an independent, not-for-profit engineering research and development organisation. Management estimates that a network of 10 ground stations is needed to meet the service requirements of LEO and GEO customers. In April 2017, BridgeSat secured an agreement with the Swedish Space Corporation to install its optical ground stations in at least three established RF ground sites.
- **Network operations centre:** this is required to operate the network and manage data delivery against customer service levels. The centre is located in Colorado. The equipment has been custom-designed by third parties to BridgeSat's specifications.

We note that free-space optical communication is relatively novel. Free-space optical communications technology from Tesat has been selected for inter-satellite links for the European Data Relay System (EDRS) programme, which provides LEO-GEO data relay services of 1.8GBps. It is in use on six EDRS associated satellites. It is not clear whether the system uses optical or RF communications for the downlinks.

Route to commercialisation

Exhibit 22: Significant milestones

Date	Achievement
March 2015	Formation
May 2017	Closed \$6.0m Series A preferred funding round, including participation from Space Angels, a prominent angel investor network of experts focused on Space 2.0
2017	Three pathfinder customers signed, including York Space Systems and ICEYE. York Space Systems is to include BridgeSat downlink technology on its satellites delivering the Harbinger Mission for the US Army. BridgeSat is to provide terminals for the ICEYE constellation of up to 18 satellites equipped with synthetic aperture radar. First space-to-ground terminal delivered to undisclosed partner
2017	First ground station designed and contracted
2017	Appointment of Barry Matsumori, formerly a senior executive at Qualcomm, SpaceX and Virgin Galactic, as CEO
2017	Agreement signed with Tesat, an established manufacturer of space-to-ground optical communications terminals, to develop interoperability with BridgeSat's ground station network
2017	Contract received for a GEO space terminal for the ETS-IX GEO satellite programme in Japan
Q118	Denver network operations centre operational January 2018. Space terminal for second customer on schedule for delivery. First customer LEO satellite with space terminal launched. This is ICEYE-X1, the world's first commercial microsatellite synthetic-aperture radar (SAR) constellation
May 2018	Agreements announced to provide space laser terminals and data services to ICEYE
H118	Six patents filed
July 2018	Design review for Japanese contract
September 2018	Raised \$10.0m in Series B financing round led by Boeing Company. Start of broader relationship under which Boeing will connect BridgeSat with its in-house experts, testing labs and other resources to help scale BridgeSat's business. Boeing appointee Craig Cooning joins board of directors
	First optical ground station operational. ICEYE-X1 satellite undergoing in-orbit testing
Q418	Operational activity commencing. Several commercial contracts in place for delivery of space terminal hardware as well as US contracts

Source: Edison Investment Research

Next steps

Management's stated objectives are:

- Three ground stations to be fully operational by the end of 2018. Currently, four sites have been prepared for installation. Equipment has been installed at the Sierra site.

- Sign 2+ customer agreements; build strong commercial revenue backlog by the end of 2018.
- Delivery of GEO terminal to Japan during 2019.
- Targeting, in total, 10 fully operational ground stations.

Federated Wireless

Analyst: Dan Gardiner

Exhibit 23: Investment summary

Subsidiary	ALM % holding	OAV* (\$m)	Co-investors	Addressable market**	Recent funding rounds
Federated Wireless (2012)	52%	\$63m	Arris Charter; American Tower, Woodford	Shared spectrum cloud-based software platform. Estimated multi-\$bn market	\$42.0m Series B funding round in September 2017

Source: Company accounts. Note: *Edison estimates based on previous funding rounds as well as recently updated group OAV.

**Allied Minds estimated addressable markets for its products.

Shared spectrum software

Massive data traffic growth is resulting in wireless spectrum becoming increasingly congested. Federated Wireless has developed a 'shared-spectrum' software platform that enables it to be dynamically allocated. Incumbents have first priority, licence holders are next and finally all other users (explained in more detail on page 33). While its technology is potentially applicable across a range of wireless frequencies and markets, it is the 3.5GHz band in the US that represents probably the biggest, and certainly the most immediate, opportunity. The FCC is seeking to open up access to this spectrum while ensuring incumbent military users are not affected by interference.

Deployment of 3.5Ghz technology is being driven by a large ecosystem called the Citizen Broadband Radio Service (CBRS) Alliance, which includes mobile, cable and fixed wireless operators, infrastructure owners and equipment makers. As a co-founder and sponsor member, Federated has been heavily involved in standard setting and is trialling its technology with leading players from across this ecosystem including a leading US mobile network operator, Charter and American Tower (the latter two are also investors). These trials should turn into commercial pilots under the FCC's Initial Commercial Deployment (ICD) program in Q219 and, as 3.5GHz licences are issued and handsets become widely available in 2019, revenue should begin ramping up rapidly.

Industry background: The need for spectrum and CBRS

Mobile traffic nearly doubled year-on-year globally in 2017, driven by increasing demand for video and the introduction of unlimited data plans. In the US it is estimated that the growth rate actually increased to over 70% as competition from T-Mobile forced Verizon and AT&T to respond with unlimited offers of their own. Ericsson estimates traffic will grow eightfold by 2023 globally and sevenfold in the US (CAGRs of 42% and 38%, respectively) as 5G deployment raises access speeds.

The spectrum needed to support this traffic growth is a finite (and expensive) resource. Not all bands are suitable for mobile services¹ and most of the valuable spectrum has either already been licensed (see Exhibit 24) or is already occupied. Historically, operators have managed data growth by offloading traffic onto Wi-Fi (which uses unlicensed 2.5GHz and 5GHz spectrum) and deploying small cells in urban hotspots. However, Wi-Fi offers limited coverage and is becoming increasingly

¹ Basic propagation characteristics of radio mean that lower frequencies (sub 1GHz) offer good coverage for low-density rural areas but can prove problematic in cities. Higher frequencies (2GHz and above) offer higher data rates and greater capacity in urban areas but coverage is more expensive as more base stations are required.

congested. Coupled with the lack of a seamless handover between LTE and Wi-Fi and the cost of configuring small cells, these solutions are far from perfect. Operators need longer-term solutions to meet the anticipated growth in traffic while preserving network quality.

Making better use of existing spectrum resources is one potential solution. The 3.5GHz band (150MHz of spectrum between 3.55–3.7GHz) is attractive as it is widely available internationally and is therefore likely to be supported by equipment makers. However, in the US it is already allocated to military (navy) radar, fixed wireless operators and some satellite download stations. Despite consuming just a fraction of the available bandwidth and predominantly operating only in coastal areas, the sensitivity of the military traffic in particular makes migrating these users to a different frequency highly problematic.

Spectrum sharing directly addresses this problem. In April 2015 the FCC passed Rule 96 (15-47A1) establishing CBRS in the US. This set out the fundamental rules underpinning how spectrum can be shared according to a three-level priority designation:

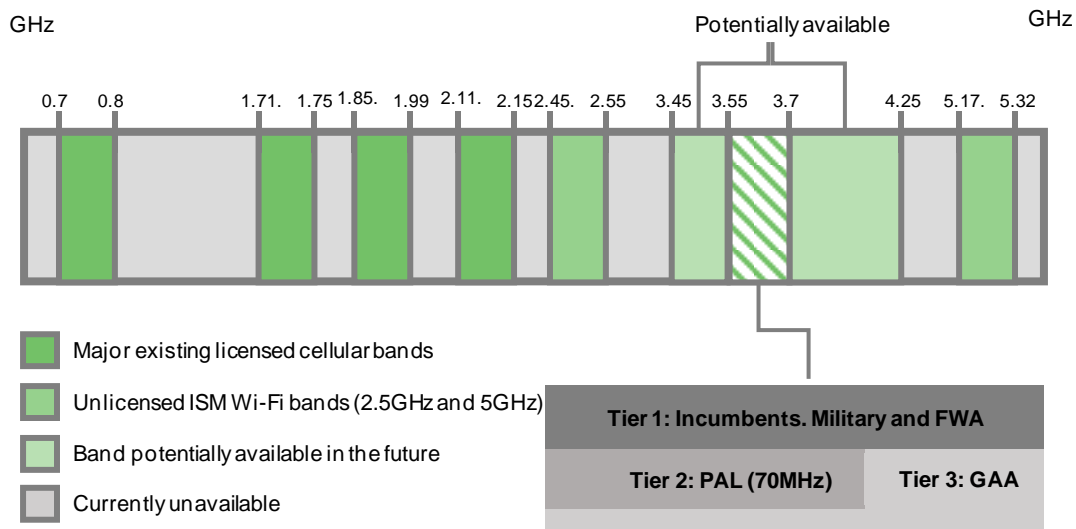
- **Tier 1 or incumbents.** In the highest tier are existing users of the spectrum such as military radar systems, satellite ground stations and wireless ISPs. These users are protected from possible interference from the lower tier (priority access licence (PAL) and general authorised access (GAA); see below) users at all times. Incumbent wireless ISPs are expected to transition to CBRS as their licences expire (mostly in 2019).
- **Tier 2 or PAL.** The FCC has allocated 70MHz (ie just under half the available spectrum) to licence holders via auction in 10MHz channels. Licence holders would have the next highest priority access: they would have to make way for Tier 1 users but would have priority over GAA users. Originally, the FCC proposed that PAL licences would cover a census tract² for a three-year term, but mobile operators, keen to use this spectrum to provide additional capacity for their national services, lobbied to increase both the area and length of each licence. In October 2018 an FCC order established a county as the licence area and specified the licence term as 10 years. Industry bodies such as PISC and WISPA³ had argued that this would raise the cost of individual licences and stifle local competition. The auction is now expected in 2020.
- **Tier 3 or GAA users.** Similar to unlicensed spectrum, GAA users are permitted to use any portion of the 3.5GHz band not assigned to higher-tier users, free of charge. With PAL licences expected to be limited to a maximum of 70MHz, at least 80MHz will be available for GAA use when not in use by Tier 1 incumbents. While a GAA service does not need a (potentially costly) licence, available capacity and service quality could be affected by other, higher priority traffic.

In addition to the priority tiers, CBRS rules define two classes of base station:

- **Category A.** Primarily designed for indoor or low power outdoor use, this type of base station has a maximum power of 24dBm (per 10MHz) and EIRP (Equivalent Isotropically Radiated Power) of 30dBm (1 watt) and is similar to existing 'enterprise-class' small cells.
- **Category B.** With a maximum EIRP of 47dBm (50 watts) this type of base station is meant for outdoor use, similar to the conventional systems used by cellular operators. Due to the frequency propagation of 3.5GHz, blanket coverage requires a high cell site density. Consequently, it is likely to be selectively deployed. Using a very high-gain antenna, outdoor base stations can also be potentially used to provide fixed wireless services.

² A census tract is a designated area covering a local population. There are 70,000 census tracts in the US.

³ Public interest spectrum coalition and wireless internet service providers respectively. See [here](#) for details.

Exhibit 24: Simplified US cellular spectrum map highlighting the CBRS spectrum


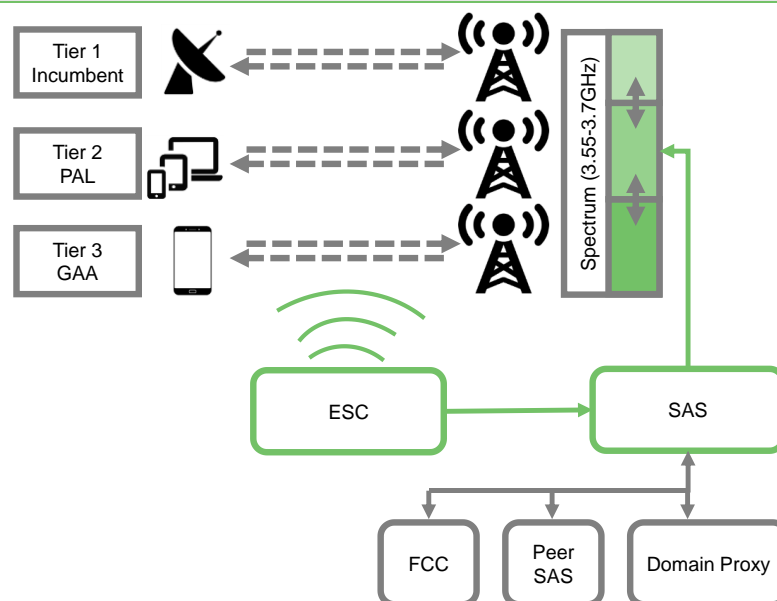
Source: Edison Investment Research adapted from FCC

How Federated Wireless' technology works

Federated Wireless offers service providers looking to use the 3.5GHz band a 'Spectrum Controller', a software platform that manages access to the shared spectrum. This platform is based on two essential components:

- **Environmental sensing capability (ESC).** A network of ESC sensors monitors traffic conditions. If an ESC detects traffic from Tier 1 users (ie a naval transmission using a radar), it informs the spectrum access system (SAS, see below) to dynamically reallocate users (either PAL or GAA) on base stations in the area to other frequencies. Federated is prioritising roll-out in coastal regions, where there is both the greatest commercial demand and chance of interference, but aims to have nationwide coverage by Q119.
- **SAS** is a cloud-hosted database of 3.5GHz CBRS-compatible base stations that stores information on their priority status and location. It monitors incumbent data from the ESC and usage data from the CBRS base stations and uses sophisticated algorithms to dynamically manage spectrum access to all users based on the three-tier priority rules.

By seamlessly managing access to this shared spectrum, this platform ultimately enables its service provider customers to offer greater capacity, higher data speeds and better coverage to their customer bases.

Exhibit 25: Federated Wireless's spectrum controller platform


Source: Federated Wireless

Market demand

Rising data demand is driving the need for greater wireless network capacity and coverage. Shared spectrum at 3.5GHz offers a solution that players from across the ecosystem are seeking to exploit. Cellular operators and infrastructure owners predominantly see the technology as a way to improve their existing services; others (ie cable operators) see an opportunity to extend their services. Federated has grouped the potential end customers into five categories: 1) mobile network operators; 2) multi-service operators (cable companies); 3) neutral hosts (network and public infrastructure owners); 4) fixed wireless ISPs; and 5) enterprises.

Federated has used this segmentation to size the potential market. It estimates, based on the pace of Wi-Fi adoption, that by 2022⁴ 5.4m US access points, c 4% share of the installed base, will be 3.5GHz enabled. It has not provided details on the assumptions underpinning this forecast but, using available market data, we have attempted to reconstruct it using the company's segmentation and making assumptions on the rate at which 3.5GHz technology must be adopted within the annual shipments:

- **Consumer cable.** There are approximately 100m homes with pay-TV access in the US. For a cable company 3.5Ghz offers the chance to extend service provision, enhance in-home networking and support MVNO initiatives. Both the leading players (Comcast and Charter, 50% market share combined) are trialling the technology. We estimate annual shipments of customer premise equipment are c 20m; assuming penetration steadily rises to reach 10% by 2022 suggests an installed base of 4.4m units.
- **Enterprise Wi-Fi.** Federated Wireless estimates there are approximately 30m enterprise Wi-Fi routers in the US. Enterprises can use 3.5GHz to relieve congested Wi-Fi networks. Ruckus, which has a 7% share of the US market and is owned by Arris (a Federated Wireless shareholder), has already announced a product portfolio that will incorporate 3.5GHz and is set to be launched in 2019. We assume annual shipments of one million units; assuming that the proportion of annual shipments incorporating 3.5GHz rises to 30% by 2022 the total installed base of enterprise access points in the US could reach 0.5m.

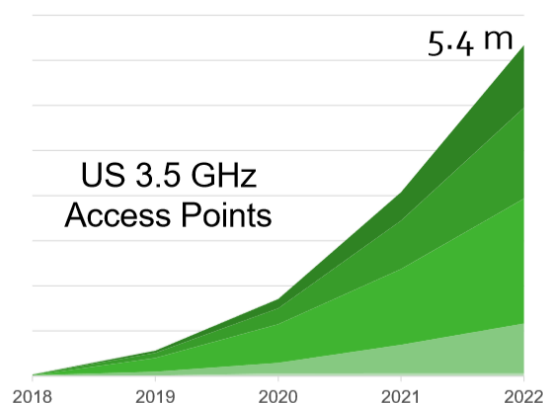
⁴ See slide 10 investor day presentation.

- **Carrier and neutral host small cells.** We estimate approximately 0.4m small cell sites have been deployed in the US and that this number doubles by 2022. Assuming that the proportion of annual shipments with 3.5GHz radios reaches 25% by 2022, the number of 3.5GHz small cells could reach 0.2m.
- **Fixed wireless access (FWA) and other.** There were approximately 2.25 million residential fixed wireless subscribers in the US in 2016 and a further five million homes without broadband. Assuming FWA growth continues and a penetration of shipments rises to 30%, there could be 0.4m FWA 3.5GHz access points by 2022.

Despite the delay to PAL issuance, substantial progress is being made. In September 2018 Federated Wireless submitted requests under the FCC's ICD program to deploy CBRS (primarily using GAA priority designation) on behalf of 15 leading operators for 16,000 sites across 47 states in the US to the FCC. These requests are expected to be approved shortly and commercial services to begin thereafter. Federated Wireless has signed contracts with Airspan and Zinwave, and fixed wireless providers Telrad and Blinq.

Nevertheless, forecasting adoption at such an early stage is fraught with uncertainty – the unforeseen delays to the issue of PALs highlights just one risk. The pace at which low-cost customer premise equipment and handsets become available often plays a big role in determining overall demand. The larger the initial demand, the quicker manufacturing cost reductions can be achieved and the more attractive the technology becomes. Federated Wireless indicates that products from 15 vendors already support CBRS including the Pixel 3 and Galaxy S10 handsets. Further high-volume handsets are expected in H219.

Exhibit 26: Federated Wireless's US access point market forecast



Source: Federated Wireless CMD presentation (slide 10). Sources referenced: Arris, March 2017 investor day presentation, IDC worldwide Enterprise WLAN forecast 2014–18, Economists incorporated and CMA Strategy consulting

Shared spectrum vs alternatives (competitive environment)

Shared spectrum at 3.5GHz is one solution to the capacity shortfall, but there are others. In time other spectrum bands may become available. The National Telecommunications and Information Administration (NTIA) has identified the 3.45–3.55GHz and the FCC has identified the 3.7–4.2GHz bands as potentially suitable for cellular use. Additional spectrum presents both a potential opportunity and a threat to Federated Wireless. Its software can be used for any spectrum issued on a shared basis, but further spectrum potentially undermines the imperative to invest at 3.5GHz.

In addition, Qualcomm (and other modem suppliers) is developing a range of technology solutions as part of the drive towards 5G. Spectrum aggregation technologies such as LTE-U and LAA aim to increase data throughput (1Gbit/s) by seamlessly switching to LTE in unlicensed 5GHz spectrum. Technology aggregation LTE-WLAN aggregation (LWA) is touted as a software upgrade that

enables the device to use licensed LTE and unlicensed Wi-Fi simultaneously. MulteFire uses LTE in unlicensed spectrum, primarily 5GHz.

In our view, none of these initiatives solve the capacity shortfall in isolation. Even if handover (between LTE and unlicensed Wi-Fi/LTEi) is improved, capacity in the licensed spectrum is likely to be constrained. Hence we see these solutions as primarily complementary to, rather than competitive with, CBRS. Nevertheless, to the extent they use existing technology or require only modest hardware upgrades, they may provide cheaper, and therefore default, solutions in the near term.

Finally, Federated also faces direct competition from alternative SAS and ESC platform providers. In total, 10 other companies have been approved by the FCC to offer SAS administration including Google, Amdocs and CommScope. AT&T (number two mobile operator in the US with a 37% market share) has announced it intends to use CommScope. However, it appears that not all these companies still plan to participate in the market. Following the recent announcement of a collaboration between CommScope and Google, maybe only three plan to roll out ESC networks. Federated is confident that its early participation in standard setting and trials with leading players has helped it establish a dominant position. While no other company has announced the total number of partners or the number of access sites, it believes it has substantially more than its nearest peers at present.

What success would look like (and valuation)

At this early stage it is very difficult to assess the potential value of Federated's software platform. To help investors frame what prospects could look like, the company provided some datapoints at the Allied Minds capital markets day. These datapoints included:

- a market forecast of 5.4m 3.5GHz access points in the US by 2022;
- the belief that it has a substantial time to market advantage, which will translate into a very high market share initially and a dominant market position over time;
- revenue of \$100 per year per access point; and
- potential to be cash flow-neutral in 2020.

To construct a forecast, we take these company-provided datapoints largely at face value and add our own assumptions:

- a 10% annual average selling price (ASP) deflator reflecting volume discounts and competition;
- a 25–50% market share range. We translate the company's share commentary into a 37.5% market share (at the mid-point). This assumption is materially below the company's current (unspecified) internal expectations;
- an 80% gross margin (assuming a typical early-stage software margin);
- an implied operating cost base of just over \$24m in 2020, growing to \$40m in 2022; and
- a nominal tax rate of 25% to reflect the potential long-term rate applicable.

Exhibit 27: Extrapolating Federated's market estimate into a company forecast

	2018	2019e	2020e	2021e	2022e
Deployments (m)	-	0.5	1.2	3.2	5.4
Mid-point market share (%)		37.5	37.5	37.5	37.5
FW access points (m)		0.2	0.5	1.2	2.0
Revenue per AP (\$)		100	90	81	73
Revenue (\$m)		19	41	97	148
Gross profit (\$m)		15	32	78	118
Gross margin (%)		80.0	80.0	80.0	80.0
Operating costs (\$m)	(20)	(22)	(24)	(30)	(40)
Operating profit (\$m)	(20)	(7)	8	48	78
Tax (\$m)	0	0	0	0	(20)
Tax rate (%)					(25.0)
Net income (\$m)	(20)	(7)	8	48	59

Source: Deployments, Revenue per AP = Federated Wireless (bold). All other assumptions: Edison Investment Research.

Taking Federated's market forecast at face value and applying our assumptions suggests a business capable of generating nearly \$150m in revenue and \$60m in profits by 2022. However, we would highlight that there is little guidance or visibility into the assumptions underpinning this forecast at this point. For example, there are substantial downside risks to adoption, share and ASP assumptions in this scenario. Conversely, this scenario does not factor in the potential for deployment in international markets (see below). To illustrate the impact of modest changes in assumptions, flexing market share to 50% increases 2022 revenue to nearly \$200m and profit to nearly \$90m; whereas reducing it to 25% cuts revenue to c \$100m and profits to \$30m.

Federated's Series A fund-raising in January 2016 valued the business at c \$60m pre-money and \$82m post-money. In September 2017 the company conducted a series B raising of \$42.0m, valuing the business at \$79.5m/\$121.5m pre/post-money. If the company can deliver on the growth prospects described in Exhibit 28, then arguably it could attract a rapid growth software-as-a-service multiple of 6–8x revenue, and a valuation close to \$1bn at the mid-point. Without evidence of financial performance, this approach is not yet warranted in our view.

This analysis exclusively focuses on Federated's US initiative in the 3.5GHz band, but there is also a potentially larger opportunity available in the long term. As highlighted in Exhibit 24, the FCC could make additional spectrum available in the US (for example the 3.45–3.55GHz, 3.7–4.2GHz and the 6GHz band) and the company is developing additional services beyond the core network spectrum management product. Finally, there is scope to replicate the shared spectrum approach in other markets; work has already begun in the UK and a similar spectrum shortage exists in Canada. These three opportunities could be significant in combination but, given they are at such an early stage, quantifying their potential is not possible currently and more funding is likely to be required to fully exploit them.

Commercialisation path and key milestones

Before commercial revenue ramps up in 2019, we believe the best way to evaluate Federated's progress is using key milestones:

Q119: complete roll-out of nationwide ESC network. Federated is aiming to be the first company to complete a nationwide roll-out of an ESC network.

Q319: launch SAS commercial product. Assuming FCC approval, Federated will be certified to launch commercial CBRS services, which should begin straight away.

H219: widespread service launch by mobile operators. While Verizon has stated that the first 3.5GHz handsets were expected by the end of 2018 and it has launched a 'commercial' service in Florida, widespread commercial deployment (ie multiple cities) is unlikely until H219. The number of access points for mobile operators is likely to be based on small cell deployment and is therefore likely to number tens of thousands.

End 2019: the first evidence of the pace of commercial deployment. Federated's market forecast suggests c 0.5m access points will be deployed by the end of 2019. While deployment is likely to accelerate, only then will it be possible to give some indication of commercial traction.

Management team and background

The Series B fund-raising in September 2017 included the first investment from leading members of the wireless ecosystem: Charter Communications (US cable), American Tower and Arris International (consumer and enterprise equipment supplier). While the investment and ownership stakes were not disclosed, with Charter, Arris and American Tower taking seats on the board, these shareholders should help guide the company in key verticals. Existing investors Allied Minds and Woodford Investment Management (also an investor in Spin Memory) contributed additional money. The management team includes:

Iyad Tarazi, President and CEO: Iyad Tarazi joined Federated Wireless from Sprint in September 2014. At Sprint he was VP of network development and led the Network Vision project where he managed a 700-strong R&D team and the development and integration of new products and technologies following the Sprint Nextel merger.

Kurt Schaubach, CTO: Kurt Schaubach joined Federated in January 2015 and plays a key role in developing, building and managing Federated's products and IP. Prior to joining the company, he served in various engineering roles at the National Rural Telecommunications Cooperative, NextWave Wireless, LCC International and Southwestern Bell. He has also served as a technology consultant to wireless network operators, equipment manufacturers and semiconductor suppliers.

Company history

Federated Wireless was founded in 2012 in Arlington, Virginia, based on technology originally developed at Virginia Tech, a university with close links to the US Department of Defense.

January 2016: Series A financing secures investment from Woodford and Allied Minds raising \$22m to accelerate development.

February 2017: SAS and ESC products received conditional certification from the FCC enabling the company to progress from technical to field trials.

September 2017: completed a \$42.0m Series B financing, with participation from Charter Communications, Arris International and American Tower, together with participation from existing investors.

September 2017: Spectrum Controller product becomes available and field trials with customers (including Charter Communications, Arris International, American Tower, a leading US mobile network operator and Telrad (a wireless broadband provider) covering all five of the verticals begin shortly after.

September 2018: submits proposal for commercial deployment to the FCC for 16,000 sites across 47 states on behalf of 15 different operators across all five target segments and based on equipment from 15 different vendors.

Precision Biopsy

Analyst: Dan Wilkinson

Exhibit 28: Investment summary

Subsidiary	ALM % holding	OAV* (\$m)	Co-investors	Addressable market**	Recent funding rounds
Precision Biopsy (2008)	65%	\$52m	Woodford Investment Management	Real-time tissue characterisation. Estimated \$4bn market (US and EU)	N/A

Source: Company accounts. Note: *Edison estimates based on previous funding rounds as well as recently updated group OAV.

**Allied Minds estimated addressable markets for its products.

Overview

Precision Biopsy is a medical device company founded on the principle of tissue spectroscopy. Utilising its ClariCore system, the company aims to distinguish between benign and suspicious (cancerous) tissue to aid in cancer diagnosis. Precision Biopsy's initial product development efforts are intended to target improvements in the field of prostate cancer, but the company's long-range goals include future applications in the field of lung, breast and kidney cancers. Precision Biopsy was formed in 2008 based on technology originally sourced from the University of Colorado. The company is in Aurora, Colorado.

Confirmatory biopsy of the prostate by transrectal ultrasound typically leaves about 20–30% of cancers undetected; about 29,000 men die in the US from prostate cancer each year according to the NCI's Surveillance, Epidemiology and End Results programme (SEER). According to the company nearly 90% of the 12 million core biopsies performed each year in the US are normal tissue, representing a substantial expense of near \$1bn.

Precision Biopsy's ClariCore System is being developed to provide accurate, real-time classification of normal or suspicious tissue to improve the overall efficiency of the entire prostate biopsy procedure. If successfully validated, registered and marketed, ClariCore could potentially improve diagnosis rates and reduce repeat biopsies as well as decreasing pathology costs.

A solution to improve the prostate cancer diagnostic rate

The SEER estimates there will be 164,690 new cases of PC and 29,430 deaths in the US in 2018. Five-year survival for all types of PC is 98.2%. Diagnosis starts with screening for serum prostate specific antigen (PSA) and/or digital rectal exam (DRE). In the event of elevated PSA levels and/or abnormal DRE, the doctor may refer the patient for further analyses such as an MRI scan or a prostate tissue biopsy. Biopsies are taken from different locations in the prostate gland under the guidance of transrectal ultrasound (TRUS). TRUS often fails to diagnose clinically significant PC and it cannot differentiate cancer lesions from benign tissue.

The standard of care at initial biopsy currently adopted by most US urologists is to take 12 to 14 "blind" systematic cores per patient. Using this method more than 50% of cancers that need definitive therapy go undetected during initial biopsy; left undiagnosed these cancers can spread to distant sites in the body. The five-year survival rate for metastatic prostate cancer is 29%. The principle challenge with today's biopsy procedure is that the biopsies are performed blindly, generally without any targeting information to indicate whether the underlying tissue is cancerous or not, which results in serious sampling errors and misdiagnoses.

Optical spectroscopy integrated with a machine learning algorithm can be used to determine whether the underlying tissue is suspicious or not. Precision Biopsy's ClariCore uses light to excite endogenous fluorophores and then detects the resulting emission spectrum at each excitation wavelength. The endogenous fluorophores (such as tryptophan, collagen, NADH, and flavin adenine dinucleotide, etc) are altered by prostate cancer at different stages. Quantitative analysis of

fluorescence spectroscopy obtained from tissue along with machine learning technology can potentially improve the diagnostic yield of prostate biopsies.

In the 200-subject clinical study conducted by the company in 2016 and 2017, ClariCore's optical biopsy needle system resulted in a very high negative predictive value (97%), indicating benign tissue. When coupled with sufficient sensitivity (85.95%) for targeting suspicious regions that could be cancerous, the technology may increase the efficiency and diagnostic yield of prostate biopsy, consequently improving patient care.

The ClariCore spectral technology

The ClariCore System consists of a single optical fibre in a needle that transmits light of different wavelengths to illuminate the tissue and enable spectral analysis. The system's analysis is based on the use of spectral biomarkers (tryptophan, collagen, NADH) that are typically altered in prostate tumours. Light is reflected back from the tissue through an optical fibre in the ClariCore handpiece and sent to a console where spectral analysis is performed using its proprietary machine learning algorithm. Validation of the machine learning technology is ongoing at the time of this publication. The console also enables the digital recording and storing of the biopsy procedure. A simple, easy-to-view remote indicator shown on the ClariCore console indicates in real time if the tissue is normal or suspicious, and the doctor can decide whether to take a core sample.

Exhibit 29: Schematic representation of the ClariCore system



Source: Precision Biopsy

We believe latest data show ClariCore's proof of principle, but confirmation in larger clinical trials is still needed, which the company is currently pursuing.

The value of a diagnostic test lies in its accuracy and predictive value. Accuracy is primarily defined by sensitivity and specificity. Sensitivity is the proportion of test results that will correctly read as positive when the disease is present, also known as the true positive rate; specificity is the proportion of test result that will correctly read as negative when the disease is not present, also known as the true negative rate.

Predictive values are the positive predictive value, that is, the probability that the disease is present when the test is positive; and the negative predictive value, which measures the probability that the disease is not present when the test is negative. One of the most important parameters for physicians is positive predictive value (PPV), which applies sensitivity and specificity to the

population. A high sensitivity rate means most cases will be correctly detected in the population. However, unless specificity is very high and the disease is prevalent in the test population, there will be many false positives (people who do not have the disease, but test positive). Clinicians expect a test to be reliably positive when it renders a positive result. If the false positive rate is high, many patients would need expensive confirmatory tests, increasing the cost burden to health services.

We note that for the ClariCore device to be successful, it needs to accurately identify suspicious tissue, meaning that it must maximise the amount of suspicious tissue that is actually a tumour and minimise the amount of tissue classified as normal that turns to be tumorigenic.

While the company has a clear regulatory strategy in the US and the EU; we speculate that in order to achieve reimbursement and be commercially successful, ClariCore will need to show a better diagnostic rate than standard 12-core TRUS biopsy, resulting in improved cancer detection and better patient outcomes.

Another application of the ClariCore System the company has under development is to map the tumour in 3D with high precision. The significance of mapping the tumour utilising company's proprietary algorithm is to image the tumour and the healthy tissue around it such that the urologist can choose to ablate (treat) the tumour locally (eg HIFU, cryo, laser, RF, vapor). The 3D mapping of the tumour would enable focal therapy for patients with prostate cancer. This product has the potential to transform prostate cancer therapy from radical prostatectomy with high incidence of side-effects to a minimally invasive in-clinic procedure at much lower costs. The company has initiated patient enrolment of its 3D mapping FIM (first-in-man) trial in Q418.

The company has also developed its own RF ablation focal therapy technology and evaluated it in pre-clinical settings. Several studies have been carried out by the company and its academic collaborators as shown in Exhibit 30.

Exhibit 30: Summary of studies

Study title	Tumour	Comments
Elastic scattering spectroscopy for detection of PC: preliminary feasibility study	Prostate	Prelim data on potential for diagnostic spectroscopy based on elastic light scattering
Autofluorescence and diffuse reflectance properties of malignant and benign breast tissues	Breast	70.0% SE and 91.7% SP
In vivo light scattering for the detection of cancerous and precancerous lesions of the cervix	Cervical	77.0% SE and mid 60% range specificities
Fluorescence spectroscopy: An adjunct diagnostic tool to image-guided core needle biopsy of the breast	Breast	Up to 81% SE and 87% SP for malignant vs fibrous/benign samples. Up to 81% SE and SP for malignant vs adipose
Minimally Invasive 16G optical biopsy needle for PC diagnosis	Prostate	Principal components produced 83.9% SE, 95.9% SP for benign vs malignant samples
Diagnosis of high-grade prostatic cancer using diffuse reflectance spectroscopy	Prostate	76% SE and 80% SP high grade vs benign
Systematic diagnosis of PC using an optical biopsy needle adjunct with fluorescence spectroscopy	Prostate	86% SE, 87% SP, 90% negative predictive value and 83% positive predictive value for benign vs malignant prostate tissue classification
Fluorescence spectroscopy can increase diagnostic yield of prostate biopsies	Prostate	Fluorescent spectroscopy with optical biopsy needle achieves high NPV for benign tissue
Human feasibility study of fluorescence spectroscopy guided optical biopsy needle for PC diagnosis	Prostate	72% SE, 66% SP and 93% NPV for in vivo and 75%, 80% and 93%, respectively, for ex vivo malignant versus benign prostatic tissue classification

Source: Precision Biopsy. Note: SE = sensitivity; SP = specificity; NPV = negative predictive value; PPV = positive predictive value.

Further studies will be necessary and additional investment is likely to be required in order to provide sufficient funding for eg ClariCore's SCORE study.

Regulatory strategy

The company will shortly commence patient enrolment in its pivotal clinical trial for final validation of the tissue classification algorithm. This trial will enrol over 300 patients and has established performance goals to demonstrate the ability of the technology to differentiate benign from malignant tissue samples with a predetermined amount of accuracy. The company intends to start

the study in H119 following a delay of several months to further optimize the algorithm. For Europe, the company intends to achieve CE mark in 2019.

While the ClariCore system is a 'new' device under FDA rules and without clear precedents to establish substantial equivalence, the company has agreed with the FDA to a Denovo 510K regulatory path in order to commercialize the system in the US.

For the 3D mapping project, Precision Biopsy initiated the FIM clinical study in Q418 while eyeing CE mark and FDA approval in 2021. Regulatory submissions for ClariCore in focal therapy will start in 2022.

Market size and competition

Grand View Research estimated that the global prostate cancer diagnostics market was worth \$2.2bn in 2017 and expects it to grow from there at a CAGR of 12.3% to reach \$5.5bn by 2025 (ref). The main drivers for this expansion are the increasing prevalence of PC, technological advancements in the field of cancer diagnostics, and increased awareness and treatments.

According to Precision Biopsy, the potential US market for ClariCore is c \$1.5bn based on one million biopsies per year at a price of \$1,500 each. Furthermore, an estimated 100,000 prostate cancer patients may be eligible for 3D mapping, which would be worth c \$300m per year and c \$500m for a focal therapy based on 100,000 procedures at \$10k each. The company estimates the European market is similar in size.

The company's main competitors in the biopsy/diagnostics area are MR/fusion biopsy systems from Philips, BK Medical, Koelis and Eigen. For 3D mapping they are MRI systems and radiologists' analyses of regions potentially affected, called regions of interest, marketed by Toshiba and Siemens. In the focal therapy area competitors include Bard, BTG, EDAP TMS and SonaCare.

While the company has achieved a category III reimbursement code for use of ClariCore system in the US, we believe the reimbursement process and commercial uptake are hard to predict since more data are needed to establish ClariCore's profile and competitive edge vs current methods. Therefore, we cannot estimate what market share it will capture or its valuation.

Management

Adam Savakus, president and chief operations officer: Precision Biopsy is led by COO Adam Savakus, who is an accomplished medical device executive with over 25 years of direct experience driving complex product development, clinical and regulatory efforts to successful outcomes. He has been a key contributor in the formation, financing and successful execution at several device companies, including the foundation of EndoSonics, a pioneer in the field of intravascular ultrasound, which is now an established standard of care in interventional cardiology (IPO, acquired by Jomed, now Volcano Therapeutics). Adam then joined a 12-person team at Adiana developing a novel transcervical sterilization method, managing the company to a successful 770-patient pivotal trial and FDA PMA Approval (acquired by Cytyc/Hologic). Most recently as EVP at Relievant MedSystems, he was instrumental in their successful product development as well as clinical and regulatory strategy for the Intracept device, which was targeted at relief of chronic lower back pain. Under Adam's leadership, the company executed a successful randomized, double-blinded Level 1 clinical study, the leading to 510(k) approval by the FDA in July 2016. He holds a BS in biophysics and an MS bioengineering, both from the Pennsylvania State University.

Dr Priya Werahera, PhD, chief scientific officer: Precision Biopsy co-founder and chief scientific officer Dr Priya Werahera has devoted more than 20 years to improving PC diagnostics and therapies as an associate professor in the departments of pathology and bioengineering at the University of Colorado. His clinical research accomplishments include the development of a computer algorithm and methodology that make it possible to use 3D computer models of prostates to demonstrate the efficacy of prostate biopsy protocols, and the initial proof-of-concept work that

paved the way for low-risk PC patients to benefit from targeted focal therapy. Dr Werahera holds two BS degrees (University of Moratuwa, Council of Engineering Institute), an MS from Oregon State University and a PhD in electrical and computer engineering from Colorado State University. He has earned several notable patents for his work in tissue classification, published more than 30 papers in peer-reviewed scientific journals and conference publications and is a senior member of the Institution of Electrical and Electronics Engineers.

John Nichols, vice president, product development: John Nichols has been building category-defining products in the medical, telecom and industrial technology sectors for over 35 years. His experience includes managing diverse, multi-discipline staff in executing the product development cycle from phase zero through to product launch. Prior to joining Precision Biopsy as vice president of product development, Mr Nichols held leadership positions in both the medical sector (Hach, Tensentric, Plexus GE Medical and Datex-Ohmeda) and the networking and telecommunications sector (Cellport, Aztek Engineering, Lucent Technologies and AT&T Bell Laboratories). He spent his first years as an engineer at Bell Labs, where he earned several patents in telecommunications. He has a BS and MS in electrical engineering from the Illinois Institute of Technology and is a member of the Industrial Advisory Board at University of Colorado Boulder and Colorado State University Fort Collins.

Sierra Yearsley, vice president, clinical operations: Sierra Yearsley has over 15 years' experience as a clinical and business leader with expertise in end-to-end clinical trial management in start-up, academic and Fortune 500 environments. Before joining Precision Biopsy, she was the senior director of clinical operations at Relevant Medsystems, a venture-backed company developing a novel therapy for the treatment of chronic low back pain. At Relevant, she led the successful execution of an international 225-patient randomised, double-blind, sham controlled trial to provide level 1 evidence for marketing clearance and support for physician adoption. At Adiana (acquired by Hologic), a women's health care company, her clinical leadership roles included managing a 770-patient international IDE/PMA to support approval of the company's transcervical sterilisation product. Ms Yearsley started her career in industry-sponsored clinical trials at Oratec Interventions (acquired by Smith and Nephew) where she worked on various clinical trials to support the company's portfolio of spine and sports medicine therapies.

SciFluor Life Sciences

Analyst: Pooya Hemami

Exhibit 31: Investment summary

Subsidiary	ALM % holding	OAV* (\$m)	Co-investors	Addressable market**	Recent funding rounds
SciFluor Life Sciences (2010)	70%	\$63m	Woodford; Invesco.	New ophthalmology drugs. Estimated injectables market \$8bn	N/A

Source: Company accounts. Note: *Edison estimates based on previous funding rounds as well as recently updated group OAV.

**Allied Minds estimated addressable markets for its products.

Overview

Based in Cambridge, MA, and founded in late 2010, SciFluor Life Sciences discovers and develops proprietary new chemical entity (NCE) drug molecules for use in the field of ophthalmology. Its focus has been on applying fluorination chemistry to design and test fluorine-containing small molecule drug candidates that can demonstrate improved potency and pharmacokinetic properties relative to existing drugs. Its lead drug, SF0166, has been studied in two separate multi-centre, randomised, 44-patient Phase I/II trials, in patients with diabetic macular edema (DME) and in patients with neovascular age-related macular degeneration (wet AMD). The company also has two preclinical assets in development, SF0274 and CNS KCNQ2/3, which it plans to bring to human studies in 2019. To date, over \$47m has been invested in SciFluor. In its most recent filing (27 September 2018), Allied Minds reduced its discounted cash flow (DCF) valuation for SciFluor due to delays in planned financing activities, which pushed back the start of its next Phase II study (SF0166 in DME) to H119 (from an earlier anticipated timeline of H218). Allied Minds announced in its February 2019 trading statement that Allied Minds and Woodford would jointly provide \$4m of funding to bridge to the Series B round to fund Phase II trials for its SF0166 topical eye drop treatment for retinal disease and position the company for growth of its platform.

Exhibit 32: SciFluor development pipeline

Product candidate	Development stage	Targeted indication	Next development steps
SF0166	Phase II	DME	Start Phase II study in 2019 (dependent on funding)
SF0166	Phase II	Wet AMD	Start Phase II study in 2019 (dependent on funding)

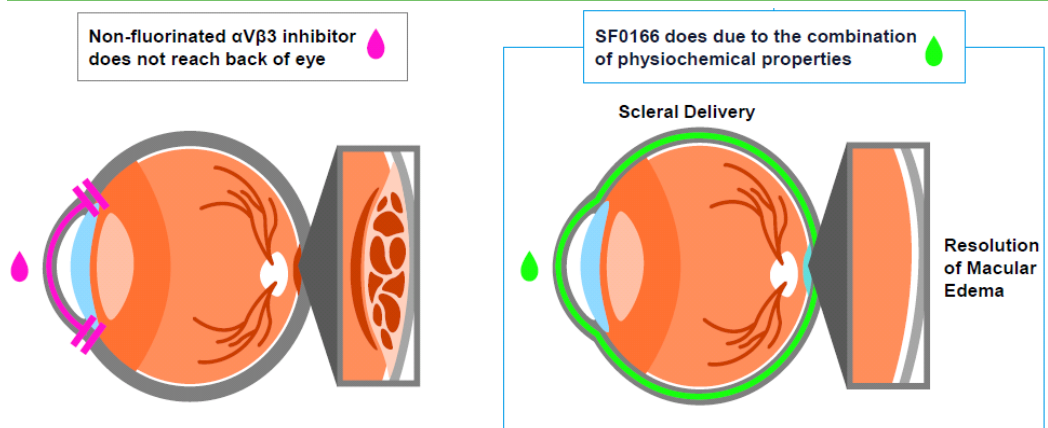
Source: Company reports

Technology overview

SF0166 is the result of a drug discovery effort to develop small molecule Integrin $\alpha\text{v}\beta 3$ antagonists with the appropriate physiochemical properties to allow distribution to the posterior segment of the eye (retina) after topical administration in an ophthalmic solution. Generally, it is extremely challenging to deliver therapeutics to the back of the eye in a non-invasive manner, given the barriers involved (anterior chamber and vitreous for topical doses, or blood-retina barrier for oral/systemic administration). SF0166 is a fluorinated descendent (a fluorine side chain was incorporated into the molecular structure) of a precursor $\alpha\text{v}\beta 3$ antagonist originally developed by Merck to treat osteoporosis (the development was abandoned prior to completion). A non-fluorinated $\alpha\text{v}\beta 3$ inhibitor would not reach the back of the eye upon topical instillation, but SF0166's fluorine component enables a topically-administered drop to travel through the sclera into the retina (and not through the vitreous), according to the company.

SF0166 selectively inhibits Integrin $\alpha\text{v}\beta 3$ and in doing so is believed to inhibit multiple factors involved with DME and wet AMD disease progression, such as angiogenesis (formation of new blood vessels, a hallmark of wet AMD), increased vascular permeability (which leads to swelling/edema and subretinal fluid accumulation), and endothelial cell adhesion and proliferation.

Exhibit 33: SF0166 distributes to the retina via sclera and not through vitreous humour



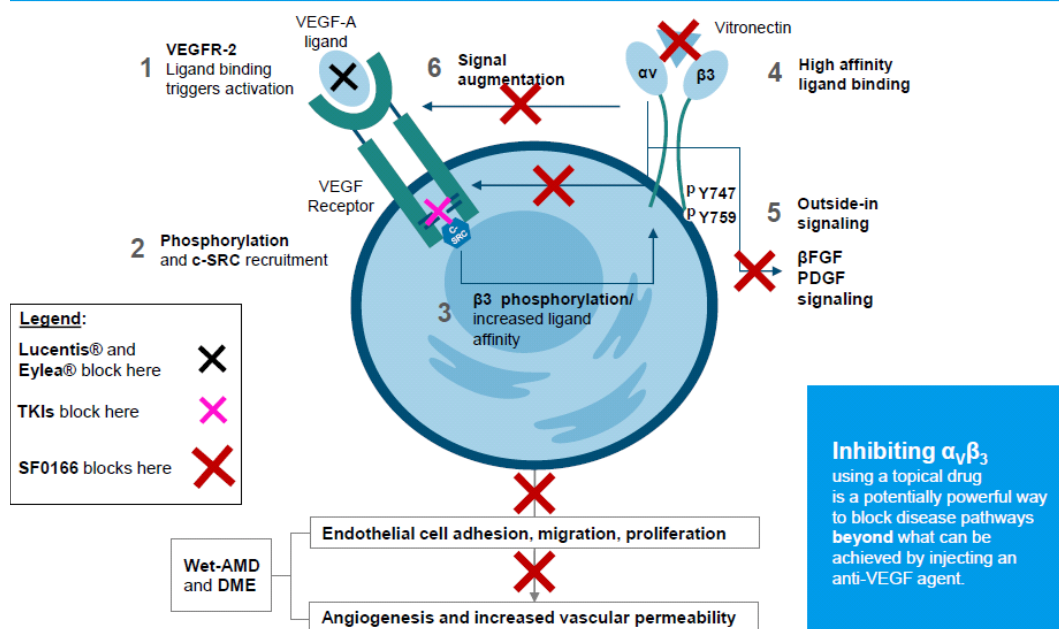
Source: SciFluor

Current standard-of-care treatments (ranibizumab and aflibercept) are administered through intravitreal (IVT) injection and generally work by blocking vascular endothelial growth factor A (VEGF-A) binding and activity. VEGF-A is a biochemical signal protein that promotes angiogenesis throughout the body and in the eye, and tends to be over-expressed in hypoxic environments.

While SF0166 also blocks VEGF-A, it may have additive effects on further pathophysiological mechanisms involved with hypoxic disorders⁵ such as wet AMD and DME, such as blocking VEGF-R2 phosphorylation and VEGF-stimulated adhesion, proliferation and migration of endothelial cells.

Exhibit 34: Mechanistic effects of $\alpha_V\beta_3$ inhibition on wet AMD or DME disease processes

$\alpha_V\beta_3$ plays Multiple Critical Roles in Growth Factor Signaling



Tsou R, Isik FF. *Mol Cell Biochem.* 2001;224:81-89.

Source: SciFluor company reports

⁵ Where there is insufficient oxygen entering relevant tissues.

Condition background and commercial opportunity

DME and wet AMD are the largest markets for medical retina treatments, particularly in developed countries. Over 11 million people in the US have some form of AMD⁶ and approximately 13 million individuals in Western Europe⁷ have the condition. Approximately 10–20% of these will develop the wet form of AMD.^{8, 9} The data on DME are less precise, but approximately 1.25 million people in the US have type I diabetes (T1D) and about 30 million have T2D. According to population-based studies, the prevalence of DME among T1D patients was between 4.2% and 7.9% and between 1.4% and 12.8% in patients with T2D.¹⁰ Hence the US prevalence of DME is between c 0.5 million and 4.0 million people, and the Western European prevalence would be expected to be comparable.

Both conditions are attributable to angiogenic or vasoproliferative factors being released into the eye in a hypoxic ocular environment, which leads to vascular leakage and in the case of wet AMD, can result in neovascularisation (the formation of fragile new blood vessels, which can distort vision and cause scarring that permanently damages photoreceptors). In the case of DME, vascular leakage leads to subretinal fluid accumulation and visual distortion.

As mentioned above, the two most commonly used drugs for these indications are ranibizumab (Lucentis, marketed by Novartis in ex-US markets and Roche in the US) and aflibercept (Eylea by Regeneron and Bayer). Eylea recorded 2017 global sales of \$5.9bn (+14% y-o-y) and global Lucentis sales were \$3.4bn (+4% y-o-y). Wet AMD and DME were the primary sources of revenue, with contributions also occurring from other medical retina indications associated with angiogenesis and/or hypoxia (such as macular edema following retinal vein occlusions, and diabetic retinopathy in patients with DME).

Both ranibizumab and aflibercept work by inhibiting VEGF-A thus blocking angiogenesis (the growth of new blood vessels). Aflibercept is a soluble decoy receptor that binds VEGF-A and placental growth factor with a greater affinity than the body's native receptors. Both of these drugs are administered through injections (often administered monthly) and each dose costs about \$2,000 in the US.

Topical delivery provides safety and convenience advantages

The key differentiator for SF0166 compared to existing standard-of-care treatments for DME/wet AMD is that it is being delivered topically through an eyedrop, as opposed to regular and repeated (generally every one to two months) IVT injections. Any IVT injection carries a small but non-zero risk of endophthalmitis (intraocular inflammation), a potentially devastating condition that often leads to total blindness. A recent multicentre longitudinal study involving over 88,000 injections between January 2006 and November 2016 found that the cumulative risk of developing infectious endophthalmitis after 60 IVT injections was 0.84% and the cumulative risk of non-infectious endophthalmitis was approximately 0.23%.¹¹

As a topical drop, SF0166 can potentially offer both patient comfort and safety benefits over the current standard of care of monthly IVT injections. Because the drug can be self-administered, there can also be savings in medical procedure costs and improved patient compliance. If SF0166

⁶ BrightFocus Foundation. www.brightfocus.org/sources-macular-degeneration-facts-figures

⁷ Wong WL, Su X, Li X et al. Lancet Glob Health. 2014 Feb;2(2):e106–16.

⁸ Buschini E, Piras A, Nuzzi R, Vercelli A. Prog Neurobiol. 2011;95:14–25

⁹ Tielsch JM, Javitt JC, Coleman A, et al. N Engl J Med. 1995; 332(18):1205–9

¹⁰ Lee R, Wong TY, Sabanayagam C. Eye Vis (Lond). 2015 Sep 30;2:17. doi: 10.1186/s40662-015-0026-2. eCollection 2015. Review.

¹¹ Daien V, Nguyen V, Essex RW et al. Ophthalmology. 2018 Jan;125(1):66–74. doi: 10.1016/j.ophtha.2017.07.005. Epub 2017 Aug 8.

can offer comparable or superior efficacy to aflibercept or ranibizumab, with its more convenient and less invasive dosing, it can potentially capture a sizeable segment of the \$9.3bn global market attributable to aflibercept and ranibizumab. There may also be the potential for the treatment to be used in earlier stages of the DME or AMD disease processes.

What do the SF0166 data look like?

Preclinical data (rabbits) showed that a single dose of topically applied SF0166 distributes to the sclera, retina and choroid (the eye's posterior structures) and remains there for at least 12 hours. Data also showed that topical SF0166 (at 5% concentration applied once daily for seven days) reduces VEGF-induced vascular leakage in rabbits to an extent comparable to a single dose of IVT bevacizumab (a VEGF-A antagonist works similarly to ranibizumab) and, at 2.5% concentration applied twice-daily for seven days, it reduces choroidal neovascularization in rabbits compared to IVT bevacizumab.

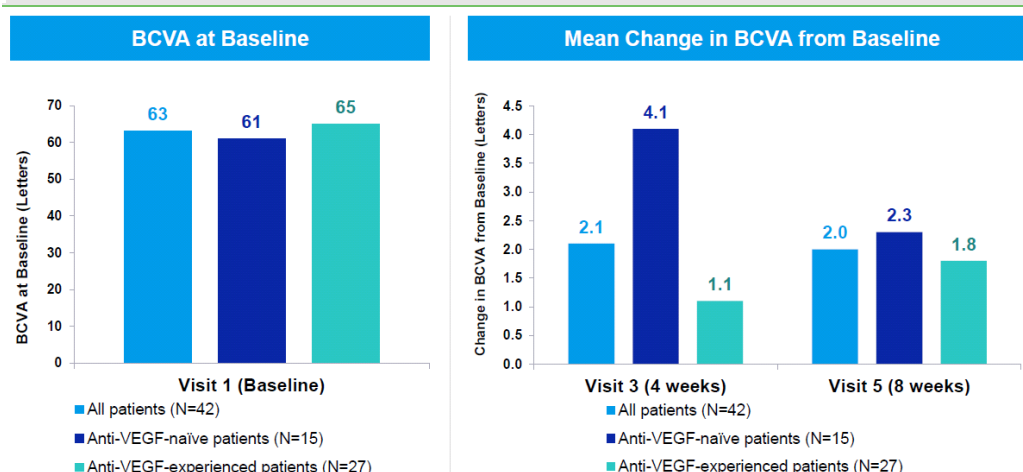
Early hints of human efficacy in Phase I/II studies

SciFluor conducted two 44-patient Phase I/II studies to assess safety and early signs of efficacy; each study tested SF0166 (subjects randomised to 2.5% and 5.0% solution concentrations in the study eye) dosed twice-daily for 28 days (with a 28-day follow-up period). In September 2017 it reported data from the 40 patients who completed the DME study. In this trial, all patients had some degree of DME and had been washed-out of any prior anti-VEGF treatment for at least 30 days.

SF0166 demonstrated biological activity in both dose ranges, with 48% (19/40) of evaluable patients showing a reduction in retinal thickness (RT) at the end of study (day 56). Improvements in visual acuity (VA) were also shown but not quantified in public data. There were no drug-related significant adverse events observed; ocular adverse events were all mild and seen in six patients with one considered possibly drug related. Altogether the DME study shows some hints of efficacy but the lack of a control group and limited stratification on mean or median improvement of thickness (in micrometres) or in VA, makes it challenging and premature to speculate whether the drug can generate clinically competitive improvements for treated patients.

In December 2017 SciFluor reported data from the wet AMD study. In addition to showing similar safety results to the DME study, investigators reported that SF0166 demonstrated signs of relevant biological activity in wet AMD. According to a panel of three retinal physicians, nine of the 42 patients who completed the study had decreases in RT and/or subretinal fluid by spectral domain optical coherence tomography.¹² It was reported that the mean improvement in VA during the treatment period among the 15 recruited treatment naïve patients, was approximately 4.1 letters at four weeks (end of treatment) and then 2.3 letters at eight weeks (end of study).

¹² Optical coherence tomography is an imaging technique that uses coherent light to capture micrometre-resolution, two- and three-dimensional images from biological media. It is particularly well suited for assessing retinal tissue and the current gold -standard for measuring the thickness of retinal structures, for the assessment of macular oedema or leakage, as well as for the assessment of vascular changes associated with wet AMD.

Exhibit 35: Effects on visual acuity of Phase I/II SF0166 study in wet AMD


Source: SciFluor company reports

As a means of comparison, we note that ranibizumab's Phase III efficacy study in wet AMD showed 31% to 37% experienced a clinically significant improvement in vision, defined as gaining 15 or more letters at 12 months. Ultimately, a longer study (eg at least six months of treatment) would be needed to compare SF0166 to an existing approved anti-VEGF drug. To be viable clinically, SF0166 would need to show somewhat comparable vision improvements to current standard of care.

Next development steps

SciFluor is working on designing its next clinical study for SF0166, which is a larger Phase II DME study that can potentially provide more comprehensive efficacy signals. The company plans to start recruitment in H119 and we estimate that the study will enrol between 150 and 250 patients. Management believes its cash burn rate will be c \$25m for the next 24 months as it proceeds with this study. Study data could occur around late 2020 and, if positive, could provide significant validation data for SF0166's possible utility in retinal vascular diseases. We anticipate that SciFluor would then be looking to out-license this asset to a major biopharmaceutical firm and given the size of the wet AMD/DME markets, the added convenience and safety of a topical formulation could lead to generous financial terms.

Competition

While current anti-VEGF treatments are very effective at providing visual recovery and stabilisation to wet AMD and DME patients, the regular monthly injections are inconvenient for many patients and several firms are developing therapies that aim to generate similar or better efficacy in a more patient-friendly manner. Roche and Novartis have late-stage monoclonal antibodies in development with superior drug delivery properties (eg brolucizumab) or that strike additional targets involved in the disease processes (eg faricimab). These products aim to provide superior visual recovery or, in the case of faricimab, offer patients longer periods between injections (potentially up to 16 weeks). Roche's port delivery system is an implant that can be inserted into the eye in a 30-minute procedure that seeks to provide a sustained dose of ranibizumab and that may only need to be refilled in six-month intervals.

Topical or oral drug delivery solutions can potentially represent the holy grail of patient convenience, but physicochemical and biological limitations can be daunting (most recently, Ohr Pharmaceuticals' squalamine topical treatment failed a Phase III trial in early 2018). In addition to SF0166, other firms are also in Phase II stages with their own topical or oral wet AMD candidates, namely Tyrogenex's orally-dosed X-82 and PanOptica's PAN-90806.

Exhibit 36: Selected competing wet AMD or DME product candidates under development

Product candidate	Company	Development stage	Targeted indication	Mechanism	Notes	Next milestones
Later-stage injection or invasive product candidates						
Brolucizumab	Novartis	Phase III (completed)	Wet AMD	Humanised single-chain antibody fragment against VEGF-A; may provide better drug delivery vs existing anti-VEGF mABs	Met primary endpoint (non-inferiority vs aflibercept) in Phase III studies reported in 2017	FDA approval in 2019–20
Faricimab	Roche	Phase III	DME	Bispecific antibody (biMAb) binding to VEGF and Angiopoietin2 (Ang2); Ang2 inhibition could improve blood-retinal barrier stability and reduce retinal vascular inflammation	229-pt Phase II (BOULEVARD) study showed significant improvements in VA vs ranibizumab; 900-pt Phase III (YOSEMITE) started Q318	Potential start of Phase III in wet AMD
Port Delivery System (ranibizumab)	Roche	Phase III	Wet AMD	Sustained delivery system of ranibizumab (implanted)	80% of pt in 179-pt Phase II study went ≥ 6 months between implant and first required refill; 360-pt Phase III (ARCHWAY) started in September 2018	Top-line data in 2021
AKB-9778	Aerpio	Phase IIb	DME and diabetic retinopathy	Small-molecule activator of Tie2 angiotensin receptor (by inhibiting vascular endothelial phosphotyrosine phosphatase, a negative regulator of Tie2)	Self-administered via a subcutaneous injection; 48-week 167-pt study ongoing where pts will receive drug or placebo daily	Results expected in Q219
Non-invasive (topical or oral) candidates						
PAN-90806	PanOptica	Phase I/II	Wet AMD	Topical small-molecule anti-VEGF	60-pt monotherapy study started in May 2018 using a new formulation. Prior formulation was associated with corneal adverse events (eg edema) in a prior Phase I study	Results expected in H119
X-82 (vorolanib)	Tyrogenex	Phase II	Wet AMD	Orally administered inhibitor of the VEGF receptor and platelet derived growth factor receptor (PDGFR)	157-pt study completed enrolment in March 2017	Data from study expected in H218
EGP-437	EyeGate	Phase I	DME	Iontophoresis platform intended to deliver corticosteroid (dexamethasone) to posterior segment	Earlier Phase 1b/IIa study (2015) reported reduction in edema in some patients	Finalising a contact-lens delivery system for in-home use prior to next trial

Source: Edison Investment Research. Note: pt = patient.

Potential market opportunity for SF0166

Given the timing of planned Phase II studies, we estimate that under a best-case scenario, pivotal Phase III studies for SF0166 in DME and wet AMD could start in H220 at the earliest, and it is likely that two Phase III trials will be needed for wet AMD. Wet AMD pivotal studies generally require large enrolment sizes (over 1,000 people) and two years of patient evaluation (primary efficacy measured at 12 months, safety and maintenance assessed at 24 months). It can take over 36 months to complete a pivotal wet AMD trial and, given the timing and filings required for regulatory approval, we estimate the earliest the product could reach to market would be around 2025.

GlobalData estimates that the wet AMD market will grow at an 8.9% CAGR through 2026. If we use a more conservative 6.0% growth rate to the \$9.3bn in sales recorded in 2017 across aflibercept and ranibizumab (the majority of their revenue is for wet AMD treatment), this would imply a target global market size of \$18.7bn in 2029 for the wet AMD and related (DME, diabetic retinopathy, retinal vein occlusions, etc) retinal markets.

To be successful and obtain market approval (in major markets such as the US and Europe), SF0166 would need to show comparable efficacy (in terms of visual improvement and maintenance of effect) to ranibizumab or aflibercept in DME and/or wet AMD. Given the drug delivery challenges associated with topical delivery compared to IVT administration, it would appear unlikely that SF0166 (even if dosed daily) would provide superior efficacy than current and emerging IVT-administered drugs (at monthly dosing). Yet even without providing superior efficacy, we assume that SF0166 could still capture a sizeable segment of the market if approved, given its more convenient self-administered topical dosing form and the potential safety advantages (no risk of endophthalmitis) in a mostly senior-aged patient population. Assuming a 15% pricing discount to IVT-administered drugs (possibly brolucizumab and faricimab may also reach the market by the mid-2020s) and 20% market share (by usage) within four years of its launch, this would imply a

global sales potential of \$3.2bn for SF0166 in 2029. Data to date are suggestive of safety with some signals of efficacy. Assuming safety and efficacy are confirmed in subsequent studies, we believe a probability of success (for commercial approval) estimate in the order of 10–20% would be appropriate for SF0166. Using the midpoint of this estimate and assuming an annual 12.5% discount rate and a 2x sales multiple could imply a present valuation of \$260m for SF0166.

Management

D Scott Edwards, PhD, vice-president and general manager: D Scott Edwards has significant experience in pharmaceutical research and development with a focus in the areas of small molecule therapeutics and medical imaging contrast agents. He held a basic research position at Dow Chemical from 1983 through to 1987 and then began his career in drug discovery and development on joining the medical imaging division of DuPont Pharmaceutical in 1988. At DuPont and Bristol-Myers Squibb, he held positions of increasing responsibility spanning discovery, pre-clinical development, clinical development and regulatory affairs resulting in multiple new drug approvals and the first paediatric extension for an imaging drug. Scott joined SciFluor in 2012 where he leads the drug development efforts including the clinical, regulatory and quality functions and manages the company's expansive patent estate. Working with specialty contract research organisations, he has overseen the clinical advancement on SF0166 through two Phase I/II trials. He holds a bachelor's degree in chemistry from the Georgia Institute of Technology and a PhD in organometallic chemistry from the Massachusetts Institute of Technology.

Allied Minds valuation

As is typical for IPCCs, the majority of value is concentrated in the largest few companies, although Allied Minds' portfolio is more concentrated than most. Since 92%+ of OAV is derived from six companies, Allied Minds' share price will clearly be affected by any major events or funding rounds that alter the value of any of these top six companies.

In addition to using OAV figures, based on historical funding rounds we have analysed each of the subsidiary businesses to assess the total potential within the portfolio. Although it is impossible to assess a precise valuation range given the limited visibility and early-stage nature of the assets, we believe that concrete evidence of operational progress (milestones achieved) should lead to the ultimate realisation of additional value in the portfolio.

As at June 2018, approximately \$405m had been allocated to the group's active portfolio companies. Of this, \$170.5m had been raised and deployed by Allied Minds, \$228.3m had been contributed by third-party investors and \$6.3m had been raised from loans and federal grants.

Determining the OAV

Allied Minds provides portfolio valuation updates with earnings reports and following any corporate actions (funding rounds or exits). At the end of each annual and half-year financial period, Allied Minds formally approves the value of all subsidiary businesses, which is used to derive the group OAV. The OAV was \$350.1m at June 2018 (vs \$395.6m for FY17), of which 92%+ was attributable to the top six subsidiaries. At FY17, 96% of OAV was valued by reference to the most recent third-party funding round. We note that at H118, the reduction of OAV was due to a new conditional term sheet for Spin Memory and lower DCF valuations in the life sciences businesses, partially offset by increases from third-party financing rounds for BridgeSat, HawkEye and Federated Wireless.

The inherent difficulty with the OAV is that it is often a reflection of the most recent transaction, rather than an audited figure or even an assessment of the underlying business model. A number of the core companies' funding rounds were completed several years ago, and, in some cases, co-investors were also investors at the parent level, rather than true external third-party investors. In

our view, to gain investor confidence, it is important that portfolio companies achieve external validation.

NAV analysis

NAV is defined as the portfolio value (OAV) plus cash at the parent level. Cash at parent level was \$84.2m at December 2017 and \$66.0m at June 2018. The change was due to \$12.3m investments in H118 and \$5.9m cash burn at the parent level. This compares to \$46m investment in FY17 and c \$6.7m cash burn at the parent level during 2017. The company has estimated parent level net cash of \$50m at end FY18 (after allocations for funding rounds for SciFluor, Precision Biopsy and Spin Memory). Following cash management measures announced in parallel, management believes that Allied Minds' cash runway has been extended into 2021.

Since 2017, funding rounds by external strategic investors at Federated Wireless, BridgeSat, HawkEye and Spin Memory have underpinned the portfolio, such that 64% of H118 NAV is either in cash or has been validated by strategic co-investors. However, despite recent bridge financing, strategic validation is still pending for two of the top six holdings, Precision Biopsy and SciFluor Life Sciences.

Looking forward, increases in OAV are clearly hard to predict, but catalysts include further funding rounds, as well as commercial progress across the portfolio.

Trading relative to NAV

Along with the broader listed IPCC sector, Allied Minds' shares traded at a premium to NAV until 2017 (as indicated in Exhibit 37 below). Allied Minds' premium peaked in excess of 2x NAV in 2015, with investors clearly anticipating healthy IRRs from the portfolio businesses.

However, since Allied Minds' announcement in April 2017 when the company wrote-down or liquidated a large proportion of its portfolio, the shares have fallen by c 72% and now trade at c 0.41x NAV. This discount clearly reflects the erosion of investor confidence regarding the underlying OAV at some of the portfolio businesses, as well as the potential for further future write-downs.

Exhibit 37: Share price relative to NAV



Source: Refinitiv data, Edison Investment Research. Note: 2014 data are based on OAV, as parent cash levels not provided.

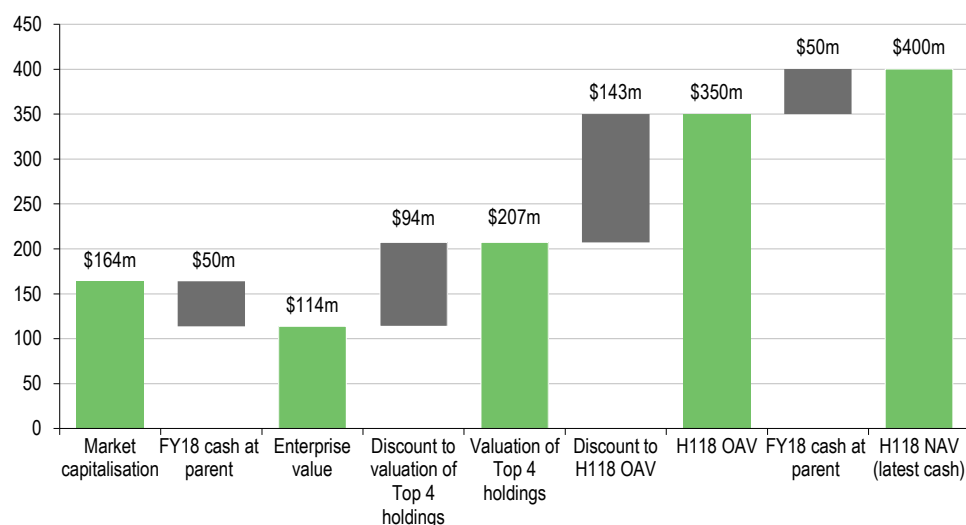
Listed peers

Listed IPCCs are typically a UK phenomenon, having mostly invested in spin-outs from British universities. As discussed above, Allied Minds differs in that it concentrates purely on US spin-outs and focuses on originating investments from US federal laboratories, with a number of which it has strong relationships.

Listed peers include Arix Bioscience, IP Group, Malin Corporation and Mercia Technologies. Some of the listed IPCCs have listed spin-outs within their portfolios, with unlisted holdings ranging from early-stage to unicorns. Following the acquisition of Fusion IP and Touchstone Innovations, IP Group is the largest IPCC with a portfolio of c 240 companies. Other peers also include listed direct investors, such as Augmentum Fintech, Draper Esprit, HgCapital and Oakley Capital.

Allied Minds' stock trades at 0.41x NAV, which is materially lower than other listed peers (eg IP Group at 0.84x and Mercia Technologies at 0.91x). We would also flag that Allied Minds' EV trades at a 45% discount to our valuation for the top four portfolio companies, each of which has been validated by external fund-raising.

Exhibit 38: Valuation bridge



Source: Refinitiv data; Edison Investment Research. Note: Priced at 25 February 2019.

Given the momentum and promising nature of the rebased portfolio, we believe this discount is unjustified. Catalysts for a re-rating include further externally led funding rounds and concrete evidence of operational progress at the subsidiary level.

Exhibit 39: Peer group comparison

	Price	Currency	Market cap (m)	NAV (m) (last reported)	Cash (m)	NAV premium/discount
Allied Minds	52.1	GBP	125.2	306	38	0.41
Arix Bioscience	158.0	GBP	213.2	258	137	0.83
IP Group	102.4	GBP	1,085	1299	259	0.84
Malin Corporation	5.50	€	251.1	402	27	0.62
Mercia Technologies	37.6	GBP	114.0	125	38	0.91

Source: Refinitiv data; Edison Investment Research. Note: Priced at 25 February 2019.

Market data: What success could look like

Our analysis of the top six businesses suggests there is significant upside potential within the portfolio. For each of the key portfolio companies, we have detailed some of the necessary milestones and operational goals required to unlock value. However, it is important to note the early-stage nature of the companies makes it impossible to articulate a precise valuation range. We also note that market size forecasts are significantly based on management assumptions.

To demonstrate what success might look like for the most promising top three technology businesses (targeting commercialisation in 2019), we have highlighted market data and/or comparable companies to provide a benchmark for valuation.

We provide a summary here, but please see the individual company analysis for more information.

Federated Wireless

In our view, the most significant opportunities lie in Federated Wireless, with growth opportunities following the important investment from Charter Communications, in September 2017. At this early stage it is very difficult to assess the potential value of Federated's software platform, but taking management's market forecast at face value and applying our own assumptions suggests a business capable of generating nearly \$100m in revenue and \$30m in profits by 2022.

Spin Memory

For Spin Memory, management has not provided any guidance on how revenues may develop. However, it is possible to draw comparisons with other public companies, for example, ARM's licence model was based on 2% per chip sold, with the company acquired by SoftBank at a valuation of 24.4x historical revenues. Applying these metrics to our \$176m estimate of Spin Memory's valuation (recognising that these multiples represent the top end of a range) indicates licensing revenues of \$7.2m from supplying IP for \$360m worth of MRAM chips. This is equivalent to 1.8% of the estimated \$20bn TAM DRAM substitution market or 7.5% of the more conservative \$4.8bn estimated MRAM market size predicted by Research and Markets.

HawkEye 360

Having launched its Pathfinder mission in December 2018 and with its initial three satellites successfully commissioned, HawkEye 360 will derive recurring revenues from providing location and spectral data on RF signals to subscribers from 2019 onwards. Management believes HawkEye 360 is the only commercial entity to have launched a satellite cluster with diverse RF signals detection, mapping and analytics capabilities, conferring first-mover advantage. As this is a new market, there are no data available on its size. Management notes that, according to P&S Market Research, the commercial satellite imagery market is forecast to be worth US\$6.9bn by 2023, indicating there is considerable potential value in commercialising other forms of space-based data collection and analytics. We note that DigitalGlobe, a global commercial provider of earth imagery and geospatial content that operates its own commercial remote sensing spacecraft, generated US\$725.4m in revenues in 2016. It was acquired in February 2017 at an equity value of approximately US\$2.4bn.

Financials

As with all investment companies, the financial statements are characterised by changes in fair value driven by the portfolio companies and are thus difficult to model.

Revenue largely consists of non-recurring engineering and service contracts and was \$5.0m in 2017 vs \$2.7m in 2016, reflecting the early stage of the portfolio businesses. Management has indicated that three of its top companies should achieve commercialisation in 2019, but in the absence of any concrete information, we forecast modest revenues in 2018 of \$6.0m.

Net loss was \$111.0m in 2017 (vs \$128.9m in 2016), reflecting the G&A and R&D spending of \$55.2m and \$49.0m respectively (vs \$55.5m and \$55.3m in 2016). As there is limited visibility at group level, we have prudently assumed relatively flat underlying costs and note that central costs should be slightly lower as a result of reduced severance payments compared to latest historic numbers.

Cash: Parent-level cash runway extended into 2021

At the group level, cash movements are largely attributed to net cash used in operations, offset by cash received from financing rounds. In FY17, group cash (and near cash) decreased by \$54.3m to

\$169.1m (from \$223.4m FY16), with \$90.8m cash used in operations. At H118, group cash was \$132.2m.

In its February 2019 trading update, Allied Minds estimated it had a cash balance at the parent level of \$50m at end FY18 (after allocations to the Spin Memory, SciFluor and Precision Biopsy financings), down from \$66.0m at H118. This compares to \$84.2m at the end of FY17 and \$136.7m at FY16. Allied Minds also indicated that cash operating expenses would be reduced by more than 40% from c \$14m to c \$8.5m pa. As part of these reductions, the CEO will be materially reducing her cash salary for 24 months (deferring the cash element to 2021), with any bonus for 2019 and 2020 payable in shares rather than cash. Additionally, Allied Minds has determined to seek strategic alternatives for its earlier-stage life science businesses, LuxCath and Signature Medical, and does not expect to allocate further funds to these businesses.

Taken together, Allied Minds believes these measures should allow it to draw out its cash runway into 2021, before any potential returns from monetisations.

The group's strategy is to maintain a liquid cash balance readily available for investment, and we note that, without a meaningful liquidity event, Allied Minds will likely return to the market to raise further funds before 2021.

Investments

During 2017, \$81.1m was invested into new and existing subsidiary businesses, which included \$35.1m from third-party investors.

At H118, total investments amounted to \$22.3m (including the Spin Memory loan syndication), of which Allied Minds invested \$12.3m. Since the period end, Allied Minds has confirmed investments of a further \$14.3m (potentially rising to \$16.8m if no further financial investors can be found for the balance of the Spin Memory funding round).

As witnessed by the recent funding rounds, most cash spent in 2018 is expected to be directed towards the main six subsidiaries, with only c \$3–5m invested into new businesses. Following the February 2019 trading update, we believe Allied Minds will now exercise tight cost control measures and direct cash only, where necessary, towards core investments.

Cash from outside investors is reflected in the cash flow under 'issuance of preferred shares in subsidiaries' and changes in fair value are reflected as a current liability (subsidiary preferred shares). In 2017, subsidiary preferred shares increased by \$40.7m to \$181.6m, largely as a result of net proceeds from subsidiary preferred rounds of \$33.9m (BridgeSat, Federated Wireless, HawkEye and Signature Medical). At H118, subsidiary preferred shares declined to \$143.4m, largely as result of a fair value adjustment at Spin Memory, offsetting the \$10.3m syndicated loan in January 2018.

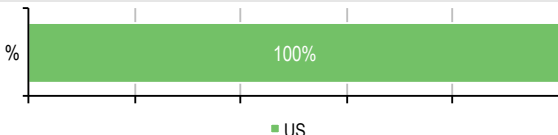
Sensitivities

- **Early-stage business risk:** inherently, the early-stage nature of IPCC portfolio businesses carries a high degree of risk and many of Allied Minds' investments are unlikely to reach their hoped-for potential. As witnessed by the liquidations in 2017, any further write-downs (particularly at the top six businesses) would likely have a negative impact on the share price. For example, recent external validation for the carrying values for the life sciences investments is outstanding and significant delays in clinical studies or even critical failures in clinical testing would likely have negative consequences.
- **Cash requirements:** a successful IPCC should have enough cash for new investments and be able to source matching investments from other institutions. Allied Minds has stated it has sufficient funds into 2021. However, we note that in the absence of material liquidity events, the company is likely to need to return to the market to raise fresh capital before 2021.
- **Lack of cash exits:** ultimately, cash exits are the key to unlocking value and although Allied Minds has been in operation for over a decade, it has yet to successfully exit an investment.
- **Pipeline:** Allied Minds' longer-term value depends on the attractiveness of its investment pipeline, which in turn rests upon the links with leading universities and research institutions. Allied Minds is investing in deeper relationships with US federal institutes but we note that, in many cases, it does not have exclusivity and therefore there is no guarantee that it will be able to continue to attractively source new investments.
- **OAV calculations:** the inherent difficulty with the OAV is that it is often a reflection of the most recent transaction or even a discounted cash flow-based valuation, rather than an audited figure or an assessment of the underlying business model. We note that there is limited visibility regarding co-investment rounds for specific companies within the portfolio.
- **Shareholder overhang:** the shares in Allied Minds are tightly held, with key shareholders having significant positions in the equity. As the share price recovers from current lows, it is possible these shareholders may sell into a strengthening share price, acting as an overhang on potential share price recovery.

Exhibit 40: Financial summary

	\$'k	2014	2015	2016	2017	2018e
31-December		IFRS	IFRS	IFRS	IFRS	IFRS
INCOME STATEMENT						
Revenue		7,715	3,300	2,664	5,001	6,001
Cost of Sales		(5,416)	(3,925)	(5,563)	(5,242)	(3,548)
Gross Profit		2,299	(625)	(2,899)	(241)	2,454
Normalised operating profit		(47,510)	(89,372)	(103,925)	(94,542)	(72,450)
Amortisation of acquired intangibles		0	0	0	0	0
Exceptionals		(1,479)	(309)	(1,365)	(2,363)	(455)
Share-based payments		(8,939)	(7,041)	(8,385)	(7,562)	(10,259)
Reported operating profit		(57,928)	(96,722)	(113,675)	(104,467)	(83,164)
Net Interest		222	670	2,318	305	1,720
Joint ventures & associates (post tax)		0	0	0	0	0
Fair value changes		0	(1,937)	(17,585)	(6,850)	48,516
Profit Before Tax (norm)		(47,288)	(90,639)	(119,192)	(101,087)	(22,214)
Profit Before Tax (reported)		(57,706)	(97,989)	(128,942)	(111,012)	(32,928)
Reported tax		0	0	0	0	0
Profit After Tax (norm)		(47,288)	(90,639)	(119,192)	(101,087)	(22,214)
Profit After Tax (reported)		(57,706)	(97,989)	(128,942)	(111,012)	(32,928)
Minority interests		12,228	20,192	32,609	35,337	(4,522)
Discontinued operations		0	0	0	0	0
Net income (normalised)		(35,060)	(70,447)	(86,583)	(65,750)	(26,736)
Net income (reported)		(45,478)	(77,797)	(96,333)	(75,675)	(37,450)
Basic average number of shares outstanding (m)		186	215	217	236	240
EPS - basic normalised (\$)		(0.19)	(0.33)	(0.40)	(0.28)	(0.11)
EPS - diluted normalised (\$)		(0.19)	(0.33)	(0.40)	(0.28)	(0.11)
EPS - basic reported (\$)		(0.24)	(0.36)	(0.44)	(0.32)	(0.16)
Dividend (\$)		0.00	0.00	0.00	0.00	0.00
Revenue growth (%)		n/a	(57.2)	(19.3)	87.7	20.0
Gross Margin (%)		29.8	-18.9	-108.8	-4.8	40.9
Normalised Operating Margin		n/a	n/a	n/a	n/a	n/a
BALANCE SHEET						
Fixed Assets		44,039	92,784	38,232	28,369	32,931
Intangible Assets		3,409	4,384	2,762	1,074	1,298
Tangible Assets		16,330	34,173	31,882	26,627	23,465
Investments & other		24,300	54,227	3,588	668	8,168
Current Assets		248,991	158,427	232,007	184,792	149,870
Stocks		2,919	1,511	2,551	0	0
Debtors		6,305	7,342	5,900	15,642	15,142
Cash & cash equivalents		224,075	105,555	209,151	158,075	123,653
Cash at parent*		n/a	n/a	136,700	84,200	50,000
Other		15,692	44,019	14,405	11,075	11,075
Current Liabilities		(62,480)	(108,974)	(155,402)	(200,202)	(187,686)
Creditors		(11,339)	(14,268)	(13,941)	(14,276)	(10,276)
Tax and social security		(947)	(395)	(458)	(4,296)	(4,296)
Short term borrowings		(213)	(228)	(115)	0	0
Subsidiary preferred shares		(49,981)	(94,083)	(140,888)	(181,630)	(173,114)
Long Term Liabilities		(717)	(863)	(720)	(867)	(565)
Long term borrowings		(338)	(112)	0	0	0
Other long term liabilities		(379)	(751)	(720)	(867)	(565)
Net Assets		229,833	141,374	114,117	12,092	(5,450)
Minority interests		4,946	10,631	20,797	59,241	54,719
Shareholders' equity		234,779	152,005	134,914	71,333	49,269
CASH FLOW						
Op Cash Flow before WC and tax		(44,618)	(85,286)	(97,290)	(88,440)	(66,512)
Working capital		(981)	2,652	468	(2,477)	(3,500)
Exceptional & other		0	0	0	0	0
Tax		0	0	0	0	0
Net operating cash flow		(45,599)	(82,634)	(96,822)	(90,917)	(70,012)
Capex		(1,764)	(23,213)	(4,087)	(1,522)	(3,000)
Acquisitions/disposals		(38,967)	(51,786)	74,816	5,853	0
Net interest		222	716	1,602	138	1,720
Equity financing		154,408	2,443	79,319	1,595	0
Dividends		0	0	0	0	0
Other		54,473	36,165	48,993	33,892	40,000
Net Cash Flow		122,773	(118,309)	103,821	(50,961)	(31,292)
Opening net debt/(cash)		NA	(223,524)	(105,215)	(209,036)	(158,075)
FX		0	0	0	0	0
Other non-cash movements		0	0	0	0	0
Closing net debt/(cash)		(223,524)	(105,215)	(209,036)	(158,075)	(126,783)

Source: Allied Minds accounts, Edison Investment Research. Note: *For clarity, Cash at parent has been broken out as a separate line from Cash & Cash equivalents. As a line item it does not form part of the calculation for Current Assets.

Contact details	Revenue by geography
100 High Street, 28 th Floor Boston, MA 02110 US +1 617 419 1842 www.alliedminds.com	
Management team	
CEO: Jill Smith	Executive VP technology investments: Simon Davidson
Joined in 2017, with 16 years of experience as a CEO at public and private companies, including DigitalGlobe (leading to IPO), eDial, SRDS LP; COO of Micron Electronics. Currently an independent director at Endo International, Gemalto NV and JM Huber Corporation.	Joined 2017, with 25 years' experience in technology sector, including managing partner of In-Q-Tel, a US-based strategic investor for innovative technologies for the US intelligence community.
Non-executive chairman: Peter Dolan	Independent non-executive director: Harry Rein
Joined in 2015, with 30 years' operating experience, including CEO and chairman of Bristol-Myers Squibb and Gemin X (VC backed oncology company sold to Cephalon).	Joined in 2017. Extensive experience in the VC sector, most recently serving as general partner for 10 years at Foundation Medical Partners. Previously, he was a founder at Canaan Partners and CEO of GE Venture Capital Corporation.
Principal shareholders	
	(%)
Woodford Investment Management	27.8
Invesco	19.5
GIC Pte	8.1
Mark Pritchard	6.3
OFI Global Asset Management	3.9
Janus Henderson	2.4
Progeny 3, Inc.	2.0
Legal & General Investment Management	1.8
Companies named in this report	
Arix Bioscience, Malin Corporation, Mercia Technologies, IP Group, Syncona, Augmentum Fintech, Draper Esprit, HqCapital and Oakley Capital.	

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United Kingdom

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