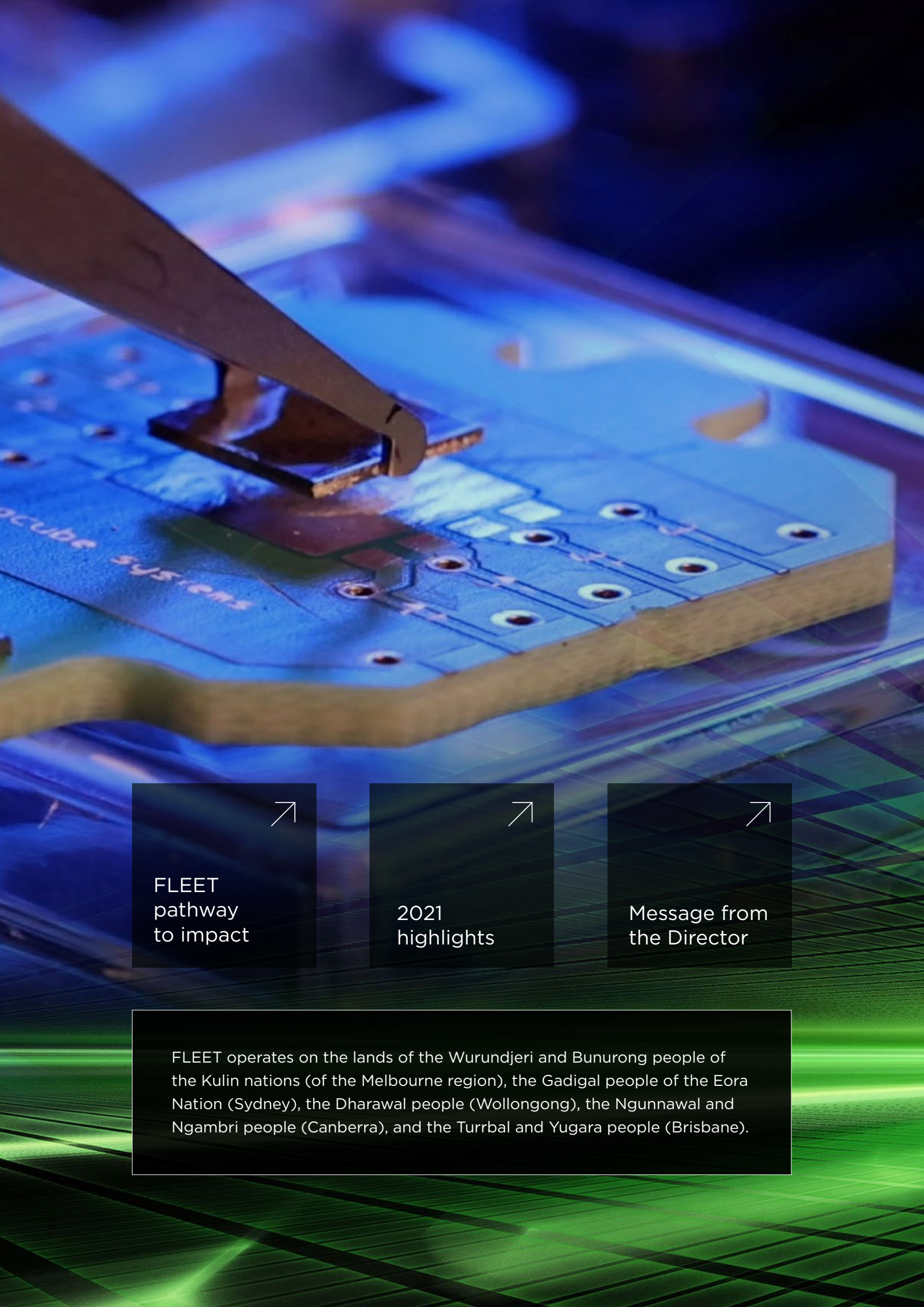

Welcome to the
FLEET
ANNUAL REPORT
2021


FLEET
ARC CENTRE OF EXCELLENCE IN
FUTURE LOW-ENERGY
ELECTRONICS TECHNOLOGIES
The ARC Centre of Excellence in **Future Low-Energy Electronics Technologies (FLEET)** addresses a grand challenge: reducing the energy used in information and communication technology (ICT), which now accounts for 8% of the electricity use on Earth, and is doubling every 10 years. The current, silicon-based technology is 40 years old, and reaching the limits of its efficiency. To allow computing to continue to grow, we need a new generation of ultra low energy electronics.
fleet.org.au
EXPLORE FLEET AR|2021



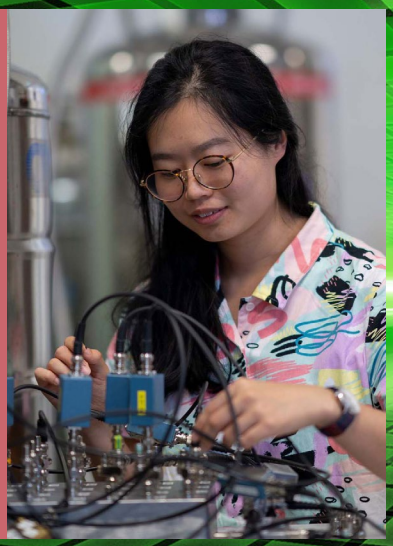
FLEET pathway to impact

2021 highlights

Message from the Director

FLEET operates on the lands of the Wurundjeri and Bunurong people of the Kulin nations (of the Melbourne region), the Gadigal people of the Eora Nation (Sydney), the Dharawal people (Wollongong), the Ngunnawal and Ngambri people (Canberra), and the Turrbal and Yugara people (Brisbane).

INTRODUCTION



FLEET at a glance

FLEET LAUNCH
12 June 2018

RESEARCH FUNDING

$6.1M
2021

$42.8M
2017-2023

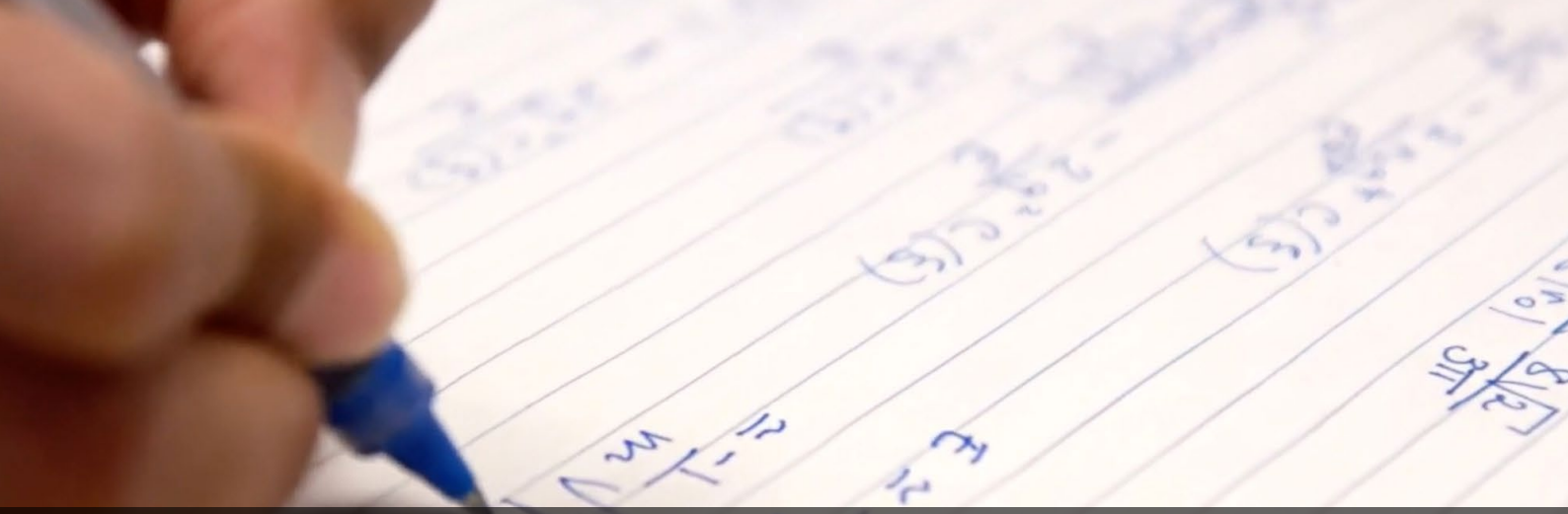
CENTRE MEMBERS AND AFFILIATES
221

INVESTIGATORS AND RESEARCH ASSOCIATES
192

EARLY CAREER RESEARCHERS
36

RESEARCH LEADERS FROM 7 AUST UNI'S
20

INT'L PARTNER ORGANISATIONS
18



Vision

FLEET's mid-term year: reflecting on achievements and looking forward to the future

IMPACT TO DATE, AND THE WAY FORWARD

2021 saw FLEET's mid-term review by the ARC. This review serves as an important milestone in the life of a centre. It is an opportunity to take stock of the Centre's accomplishments and to examine what is working well and what isn't.

The review also serves as a pivot point to re-orient the Centre's focus – from building capacity and ramping up the research, towards building a lasting legacy and a sustainable future for the Centre's research program.

REFLECTING ON ACHIEVEMENTS

The 2021 mid-term review was a helpful prompt to reflect on the achievements of FLEET of which we are particularly proud.

Foremost is the building of a unique and powerful interdisciplinary network of researchers. FLEET started with a vision of integrating disparate scientific threads – topological states of matter, atomically-thin materials, cold atomic gases, ultra-fast laser science – into a coherent whole, tied together by the vision of using dissipationless conduction in novel quantum systems to reduce the energy used in computing.

Ensuring that this whole is greater than the sum of the parts has required an active effort to enable communication and understanding across disciplines and to foster a sense of investment in FLEET's mission among our members.

The result has been a success. Cross-node publications grew from 3% in 2017 to 15% in 2021, and now most of FLEET's publications (61%) are collaborative, involving multiple chief, associate and partner investigators and/or nodes.

FLEET has also more than doubled its links with aligned national and international research institutions, adding – we've added 25 new collaborating organisations, including 11 new Partner Investigators and 16 new research associate investigators. Anecdotally, we have formed many vibrant and lasting collaborations, enabling promising new research avenues we didn't even dream of at the outset of the Centre.

FLEET's unique interdisciplinary network facilitates high-impact research. FLEET set a goal of 20% of our research papers being published in journals with high impact (impact factor greater than 7), and in the first five years an astounding 55% of papers were in high-impact journals. FLEET excellence is recognised internationally; members were invited to present their research at international conferences 146 times from 2017 to 2021, meeting our aspirational KPI of 148 even though conference opportunities were significantly impacted by the pandemic.

INNOVATION

It is not enough for Centres of Excellence just to do excellent research; we have a unique opportunity and duty to change the culture in which research is done. FLEET set out to create a more diverse and inclusive working environment in STEM. FLEET pioneered family-friendly workshops, which was a bold experiment at the start but has turned out to be a resounding success and has provided an exemplary model for research institutions worldwide. Uptake by FLEET members bringing their families to workshops has been very high, creating a more welcoming and inclusive environment for everyone. Countless times, international to visitors to FLEET's workshops have commented that they were absolutely amazed that this was possible and thrilled by the success!

FLEET hypothesised that women in STEM might be underserved by narrowly focused recruitment searches, and developed the Women in FLEET Fellowship program in response. By recruiting broadly across all areas of FLEET, the WIF program received 68 applications from talented women scientists, compared with a total of 28 applications from women received in 15 previous targeted searches. The Australia Research Council (ARC) was briefed on the successful strategy, and FLEET has this year expanded the program to target diverse groups as well as women.

FLEET is unique among Centres of Excellence in asking all of its members to contribute 20 hours of outreach a year. Not surprisingly, this has made FLEET an outreach powerhouse (FLEET members have reached 900 teachers, more than 21,000 students and over 33,000 public members). But we also found an added benefit from this innovation: our members report that they value the experience they have gained in science communications, and their CVs are stronger as a result.

SUCCESSFUL MID-TERM REVIEW

FLEET's mid-term review was conducted in May 2021 with a panel appointed by the ARC interviewing people from all levels of FLEET's membership over two days. Our members represented FLEET superbly, and the panel found FLEET was performing to an excellent standard against most of the review criteria. The comments of the review panel were constructive in nature and focused on enabling FLEET to make the most of the excellent capacity it has built to leave a lasting legacy of achievement, and a sustainable future for its research mission.

FLEET'S LEGACY

In response to the mid-term review, along with feedback from FLEET's advisory committees, FLEET is reorienting its strategic plan to focus on the legacy of the Centre.

A major part of this new strategy will be to direct half a million dollars in strategic funding to build a new Translation Program modelled on the successful program of the Engineered Quantum Systems (EQuS) Centre of Excellence. The program will allow higher degree by research (HDR) students, postdocs and investigators to pursue translational impacts of their FLEET research.

FLEET will also re-focus its outreach and communications activities to better measure the impact of our outreach programs on the public, and to better engage industry and policymakers to build a sustainable future for FLEET research.

This is an exciting period in the life of our Centre, when we can take stock of the excellent research network and capacity we have built and dream big about how to use that capacity to have the greatest impact on the future.

FLEET's legacy will be:

- Increased understanding of quantum materials and electronic devices, and new concepts for low-energy electronics at the frontier of science
- The next generation of science leaders, trained in the electronics of tomorrow
- A capacity for quantum materials and electronic devices research in Australia
- Strong links to international excellence, and ongoing partnerships between industry, academia and government, ensuring that FLEET science has impact
- Translation of FLEET science to industry
- Increased diversity in STEM and models for more inclusive research collaboration
- Recognition of the grand challenge of sustainable computing by government and society.

FLEET's grand challenge

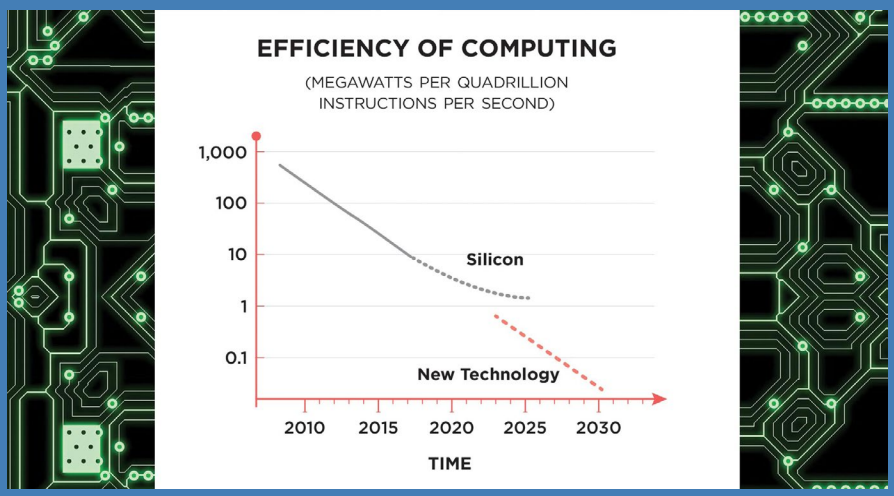
FLEET's mission is to enable continuing growth of computing without that growth being throttled by the availability and costs of energy. We will do this by developing a new transistor that can switch at lower energy.

CHALLENGE: A SUSTAINABLE FUTURE FOR COMPUTING

Computing provides overwhelming benefits to the community and economy. FLEET's mission is to enable continuing growth of computing without that growth being 'throttled' by the availability and costs of energy.

FLEET addresses a grand challenge: reducing the energy used in information and communication technology (ICT), which already accounts for about 8% of global electricity consumption and is doubling every decade.

The current, silicon-based technology (CMOS) is 40 years old and reaching the limits of its efficiency.



Fundamental physics indicates that computing efficiency could still be thousands of times better, which inspires us to search for a replacement technology. Using computers consumes energy. Lots of energy.

Computers work by activating microscopic switches called transistors – a couple of billion of them are packed into each small computer chip.

And each time one of those transistors switches, a tiny amount of energy is burnt.

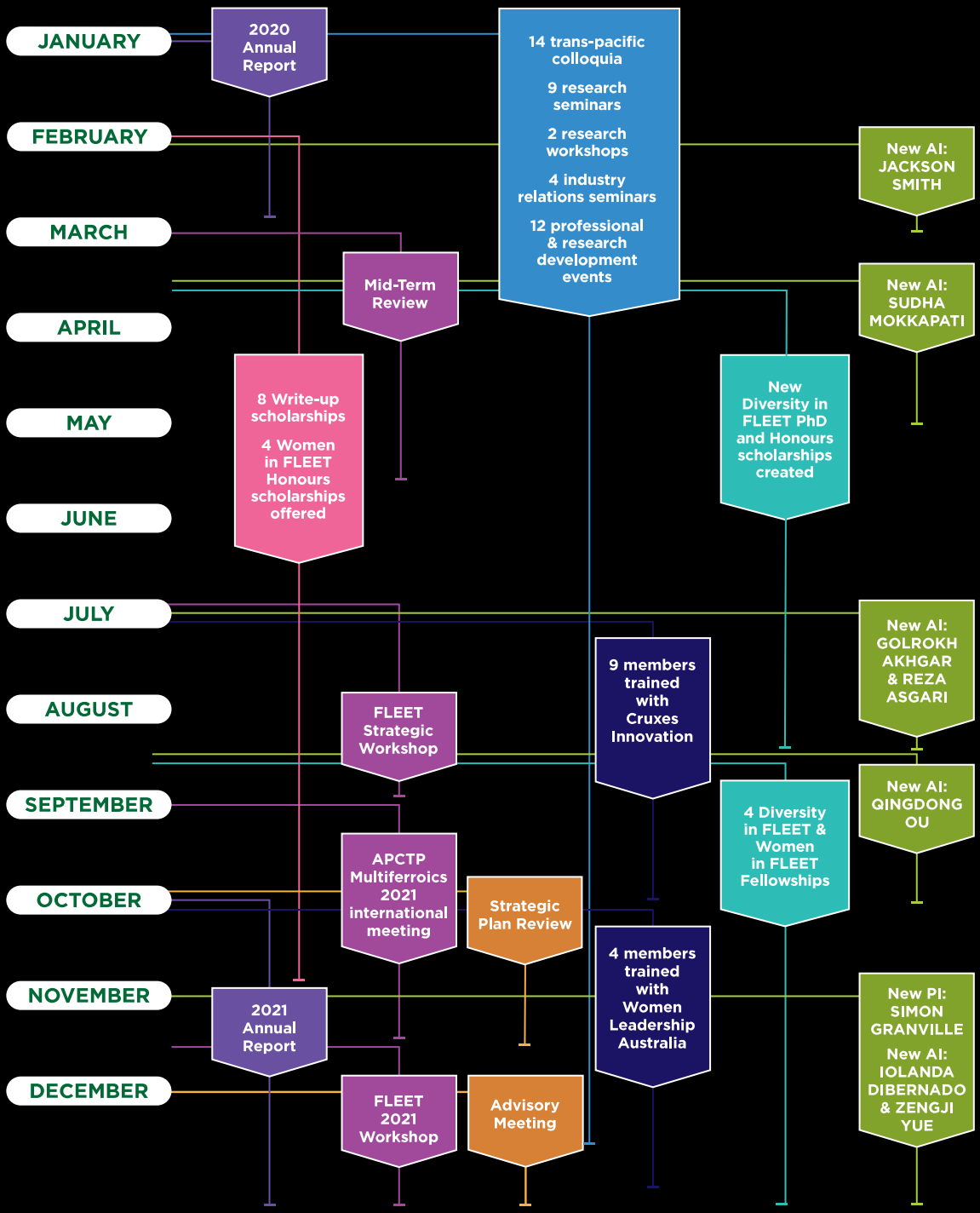
Consider the billions of transistors in each small computer chip, each switching billions of times a second, and multiply that by hundreds of servers in hundreds of thousands of factory-sized data centres.

For many years, the growing energy demands of computing were kept in check by ever more efficient, and ever more compact computer chips – a trend related to Moore's Law, which observed that the size of transistors halved around every two years.

But Moore's Law is already winding down, and will probably be declared dead in the next decade. There are limited future efficiencies to be found in present technology.

The January 2021 Decadal plan for semiconductors identifies ever rising energy demands for computing vs. global energy production as a 'seismic shift' that is creating new risk, predicts that global computing capacity will be strongly limited by energy in 1-2 decades. The Plan states that new computing paradigms offer opportunities with dramatically improved energy efficiency.

Timeline


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
2020 Annual Report
14 trans-pacific colloquia
9 research seminars
2 research workshops
4 industry relations seminars
12 professional & research development events
New AI: JACKSON SMITH
Mid-Term Review
New AI: SUDHA MOKKAPATI
8 Write-up scholarships
4 Women in FLEET Honours scholarships offered
New Diversity in FLEET PhD and Honours scholarships created
New AI: GOLROKH AKHGAR & REZA ASGARI
9 members trained with Cruxes Innovation
FLEET Strategic Workshop
New AI: QINGDONG OU
4 Diversity in FLEET & Women in FLEET Fellowships
APCTP Multiferroics 2021 international meeting
Strategic Plan Review
4 members trained with Women Leadership Australia
New PI: SIMON GRANVILLE
New AI: IOLANDA DIBERNADO & ZENGJI YUE
2021 Annual Report
FLEET 2021 Workshop
Advisory Meeting

FLEET 2021 highlights

4
Diversity and Women in FLEET postdoctoral fellowships created

FLEET Sustainability and Translation Plans created

1
New partner investigator further strengthens FLEET partnership with MacDiarmid Institute

3
FLEET ECRs chosen among the 17 'Tools of the Trade' published by Nature Physics Review

BLOG
Blog post 'Sloshing of quantum liquids' led by Eliezer Estrecho reached over 17k people

FLEET Ask a Physicist Facebook page launched

FLEET Translation Program launched

Increased online reach: doubled number of website visitors, significantly increased reach on Facebook and Linkedin

Two provisional patents filed: Negative capacitance topological quantum field-effect transistor (Monash) & Semiconductor device with a crystal heterostructure (UNSW)

14
PhD completions despite pandemic lock-downs and lock-out-of-labs

1
ARC Future Fellowship funded to FLEET investigator

3
ARC DECRA and two other competitive Fellowships funded to FLEET ECRs

Message from the Director

2021 was a year to take stock of our activities, refocus our efforts, and fine-tune our strategies to ensure FLEET has maximum impact through the life of the Centre and beyond.

As examples of high-impact strategic efforts in 2021, FLEET launched a major new initiative to boost translation of FLEET research, and expanded its groundbreaking Women in FLEET Fellowship program to diverse groups under-represented in STEM.

FLEET continues to adapt its outreach, communications and mentorship programs to maintain leadership through and beyond the pandemic.

FLEET's research continues to gather momentum. FLEET researchers have:

- Trained their sights on novel magnetic topological materials and electronic control of magnetic devices, with numerous breakthroughs this year
- Presented the Centre's concept for a negative-capacitance topological transistor at the prestigious IEEE International Electronic Devices Meeting in 2021, with benchmarking indicating it can reduce energy by an order of magnitude compared to state-of-the-art silicon devices
- Demonstrated the world's first dissipationless flow of exciton-polaritons at room temperature, and, bringing things full circle, showed that light could be used to engineer new topological phases in exciton-polariton systems.

More information on these and other research highlights follow below.

NEW STRATEGIC ACTIVITIES

As a result of feedback from FLEET's mid-term review, FLEET has launched two major new strategic initiatives in 2021.

FLEET has devoted half a million dollars to a new Translation Program that will let HDR students, postdocs and investigators pursue translational impacts of their FLEET research. FLEET has engaged an expert translation coordinator to oversee the program, working with FLEET

members to help identify new projects and shepherding them through the process of working with universities and industry. As part of this program, FLEET will also be offering new training workshops focused on giving FLEET members the skills they need to make an impact with their research (see **FLEET Translation Program**).

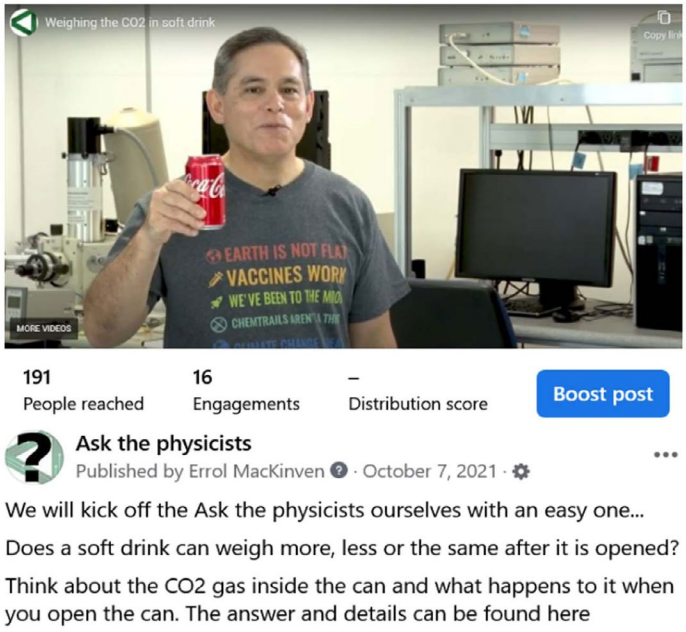
FLEET is also expanding the Women in FLEET Fellowship program to diverse groups under-represented in science, including (but not limited to) Aboriginal and Torres Strait Islander Australians; gay, lesbian and gender nonconforming persons; people with disabilities; and those with disadvantages due to background, refugee or socioeconomic status. FLEET has started recruiting and will offer four such fellowships in 2022 (see Diversity in FLEET Fellowships).

ONLINE INNOVATIONS

The pandemic continues to pose challenges, and FLEET has had to rethink many traditional face-to-face activities and innovate new virtual solutions. FLEET adopted a new online mentorship tracking application, Mentorloop, in 2021, which aids in establishing and enhancing mentor–mentee relationships and provides training and feedback to enable better mentorship.

FLEET's online communications continue to exceed KPIs, and FLEET has again increased its KPIs for mentions of FLEET research in the media and unique hits to Centre website.

FLEET has maintained its high outreach impact, despite the pandemic's challenges to public outreach activities, by creating new, in-depth teacher resources, building on our popular home science videos for younger children and creating a new a new 'Ask the physicists' Facebook page.



RESEARCH HIGHLIGHTS

The development of new quantum materials with new properties (Research Theme A) underpins FLEET's research. In 2021, we made significant progress in developing magnetic topological materials in which magnetic order can stabilise new topological phases, such as the quantum anomalous Hall effect, which are much more robust to disorder. FLEET researchers at the University of Wollongong (UOW), Monash and RMIT used two different magnet dopants, samarium and iron, to modify the topological insulator Bi_2Se_3, creating an ideal combination of robust ferromagnetism, a large bulk bandgap and large magnetism-induced surface bandgap (44 meV, much greater than room temperature), and very high charge carrier mobility. A theory/experiment team at Monash worked with the Advanced Light Source at Lawrence Berkeley National Lab (USA) to directly observe the large magnetism-induced bandgap in $MnBi_2Te_4$ two-dimensional (2D) films that exhibit the quantum anomalous Hall effect. They demonstrated that monolayer $MnBi_2Te_4$ is a wide bandgap 2D ferromagnetic insulator (of which only a few examples were previously known).

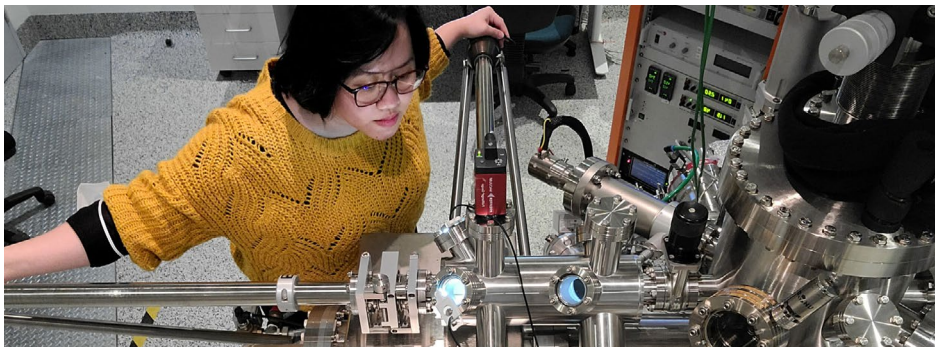
FLEET researchers at Wollongong and ANSTO won an ARC Linkage award to study the applications of topological materials in thermoelectricity, which is a promising means to

scavenge waste heat from industrial processes and turn it into useful electricity.

New techniques to modify materials to create useful devices (Research Theme B) are also critical for FLEET's mission. FLEET researchers have pioneered the technique of using a voltage signal to electrochemically alter the properties of a working device. In 2021, FLEET demonstrated that this electrochemical gating effect could be used to enhance magnetic interactions in the 2D van der Waals material TaS_2 by inserting protons into the material. A similar technique was used to insert protons into the near-room-temperature 2D van der Waals ferromagnet Fe_5GeTe_2, producing the highest carrier densities achieved in that material and revealing a new electrochemically- controlled ferromagnetic-to-antiferromagnetic phase transition.

Liquid metals have emerged from FLEET research as a surprisingly powerful research platform with an extraordinary range of applications. FLEET researchers have used the surface of liquid metals to fabricate new atomically-thin materials that are now finding use in projects across FLEET. In 2021, FLEET researchers found that liquid metals could be used to create voltage-controlled devices, such as pumps with no moving parts, and demonstrated miniature chemical reactors driven by liquid metal pumps. FLEET's liquid-metals research led to the launch of a spin-off company Liquid Metals Plus in 2021 by Kourosh Kalantar-zadeh (UNSW) and Torben Daeneke (RMIT). The company is exploring application of liquid metals in materials synthesis and carbon capture and storage.

RESEARCH THEME 1

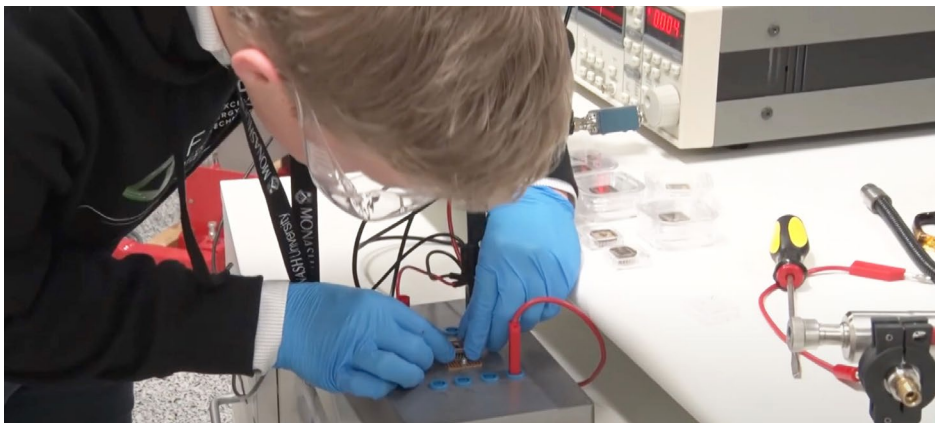


FLEET's Research Theme 1 is developing the concept of a topological transistor for low-energy electronics. In 2021 a UOW-Monash-UNSW team demonstrated that a particular topological transistor concept called the topological quantum field-effect transistor (TQFET) can beat 'Boltzmann's tyranny' and switch at voltages lower than the limit set by room-temperature thermodynamics in a conventional transistor. The concept has been developed further by FLEET researchers at Monash, RMIT, UOW and UNSW who have proposed that the TQFET can be integrated with ferroelectric materials with effective negative capacitance to create a negative-capacitance TQFET (NC-TQFET). The team benchmarked the NC-TQFET theoretically against conventional silicon devices, demonstrating that it could use eight times less energy than a similar-sized silicon counterpart.

FLEET Theme 1 researchers continue to improve understanding of novel 2D topological materials. In 2021, FLEET researchers at RMIT and UNSW measured the magnetic quantisation axis and directly demonstrated topological spin-momentum locking in the edge states of 2D topological insulator WTe_2, a critical property for dissipationless transport of current along the edges of a 2D topological insulator.

Topological insulator electronics devices now feature as a promising 'beyond CMOS' technology in the 2020 IEEE International Roadmap for Devices and Systems, and in 2021 FLEET contributed updated information for the 2022 edition of this important industry roadmap.

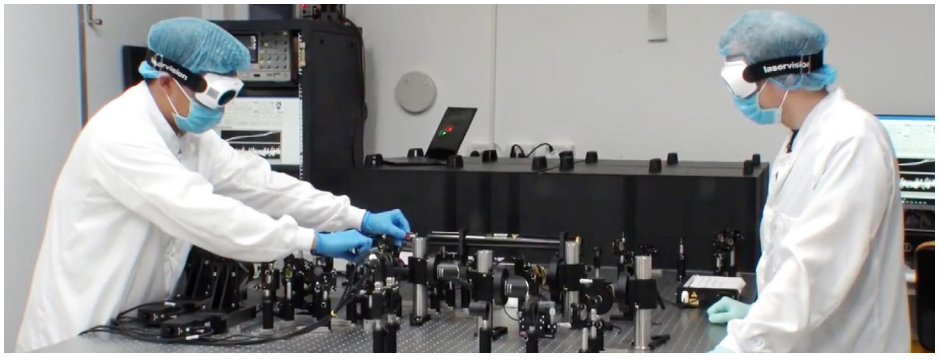
RESEARCH THEME 2



FLEET's Research Theme 2 aims to use dissipationless flow in exciton or exciton-polariton superfluids for low-energy devices. FLEET's team are now world leaders in the race to exploit dissipationless phenomena in 2D van der Waals semiconductors for room-temperature applications. In 2021, the team was the first in the world to demonstrate room-temperature dissipationless transport of exciton-polaritons in monolayer semiconductor WS_2. The team is also exploiting the unique properties of the half-light half-matter exciton-polaritons to create new kinds of topological states. Spatial patterning of light creates patterns that change not only the energy of the exciton-polaritons, but also their rate of creation and annihilation, allowing new 'non-Hermitian' topological states, which are difficult to achieve in other systems.

Theme 2 researchers have also directly visualised the existence of biexcitons (bound pairs of excitons) in monolayer semiconductors using coherent ultra-fast spectroscopy. The Theme 2 theory team continues to make advances in understanding interacting polariton systems, including how polaritons interact with each other and with free charge carriers, and how quantum correlations arise in confined polaritons.

RESEARCH THEME 3



FLEET's Research Theme 3 aims to use light to control superfluidity and topology, creating new paradigms for low-energy devices. In 2021, Theme 3 researchers at Swinburne University of Technology observed the dynamics of an ultra-cold atomic cloud that has suddenly been switched from a normal gas to a dissipationless superfluid state. Theme 3 researchers developed a comprehensive theory of vortex

dynamics and pinning in superfluid flows. In related work, FLEET researchers have also observed for the first time the fluid-like flow of (non-superfluid) electrons in channels of a conventional semiconductor with very low disorder.

In the process of using ultra-fast light to modify the properties of 2D semiconductors, Theme 3 researchers at Swinburne and Monash found that they could use machine learning to disentangle the complex information in the optical spectra of 2D materials, allowing them to better understand how doping, strain and disorder in solid state materials affect their optical properties.

FLEET'S STRATEGIC PRIORITIES

- Enable discoveries at the scientific frontier
- Develop next generation of science leaders
- Establish synergistic partnerships
- Foster equity and diversity in STEM
- Promote public STEM literacy
- Facilitate communication

FLEET'S CENTRE PRIORITIES IN 2022

- Communicate FLEET's legacy internally and externally
- Implement the Centre's new translation and sustainability plans (see **strategic plan**)
- Launch the **FLEET Translation Program**
- Focus on industry mentoring and internship programs

> I think there is a genuine interest in collaboration among members at different nodes. Folks are always willing to have a chat about your data, how to analyse it, help measure samples, grow samples etc. It's not just because it's a KPI that people work together; I think they actually want to.
>
> **FLEET MEMBER SURVEY**

IMPACT

FLEET pathway to impact

Transformational research

FLEET PATHWAY TO IMPACT
2017-2021

FLEET envisions extending the information technology revolution sustainably into the future through a new, more energy-efficient electronic technology developed in Australia.

To achieve its mission, FLEET conducts research into new, atomically-thin, electronic materials and new topological physics that will allow transmittal and switching of electrical currents with minimal energy dissipation.

Since its commencement in June 2017, the Centre has made remarkable progress in placing Australia at the forefront of international electronic technology research through the development of the scientific foundation and intellectual property for future low-energy electronic systems.

INPUTS

$33.4M
COMMONWEALTH FUNDING

$9.4M
CASH INVESTMENT FROM COLLABORATING ORGANISATIONS

$19.6M
IN-KIND CONTRIBUTION FROM COLLABORATING ORGANISATIONS

7
EXISTING INFRASTRUCTURES: AUSTRALIAN UNIVERSITIES

18
EXISTING INFRASTRUCTURES: PARTNER ORGANISATIONS

80
INVESTIGATORS

ACTIVITIES

POSTDOCTORAL RESEARCHERS BEING TRAINED

HIGHER-DEGREE RESEARCH STUDENTS BEING TRAINED

WORKSHOPS AND CONFERENCES HOSTED

SKILL DEVELOPMENT WORKSHOPS HELD

HOME SCIENCE ACTIVITIES DEMONSTRATED

OUTPUTS

PUBLICATIONS

PATENTS

PhD COMPLETIONS

POSTDOCTORAL RESEARCHERS TRAINED

RESEARCH PRESENTATIONS GIVEN

MEDIA MENTIONS

OUTCOMES

1

SPIN OFF

6866

CITATIONS

40

FLEET H-INDEX

2

INDUSTRY FUNDED PROJECTS

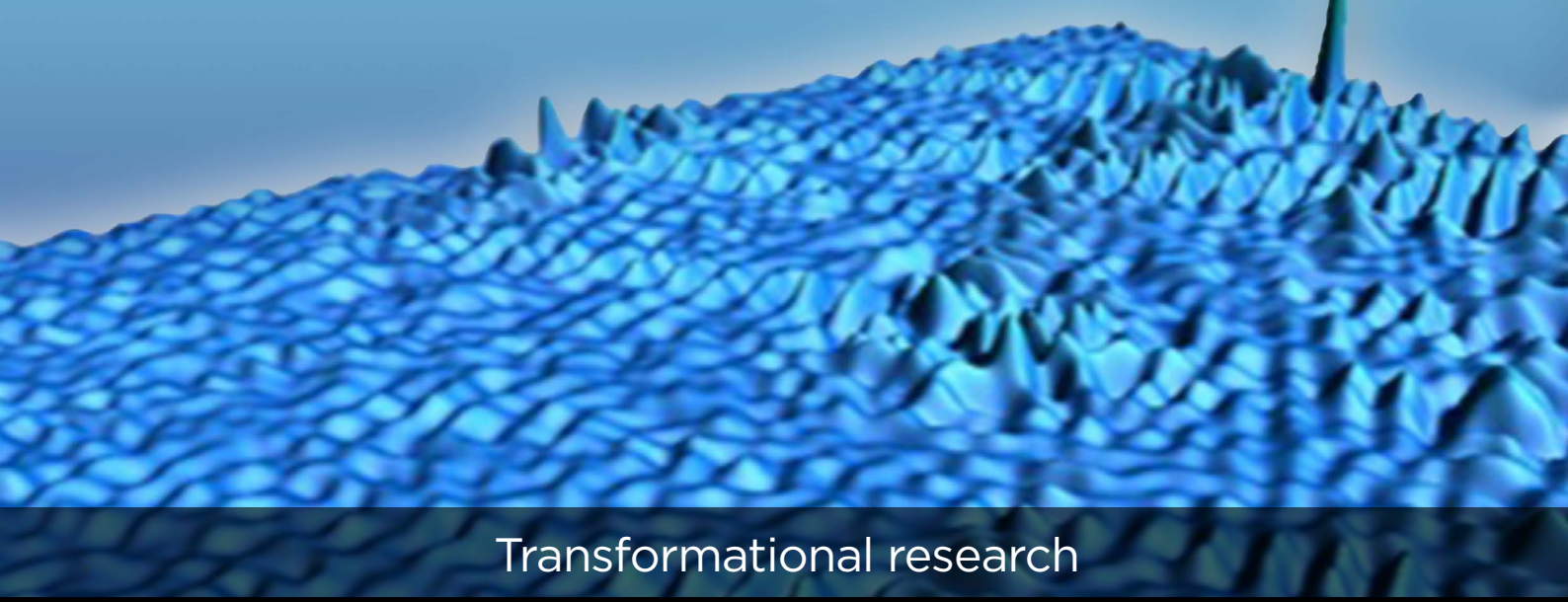
3

LINKAGE PROJECTS

"TOPOLOGICAL TRANSISTORS" INCLUDED IN THE INTERNATIONAL ROADMAP FOR DEVICES AND SYSTEMS – BEYOND CMOS

IMPACT

- Capacity for world-leading research in quantum electronic materials and devices
- Australian leadership in beyond-CMOS device research
- Foundational IP for new device concepts and processes
- New technologies using quantum electronic materials
- Innovations for inclusive, diverse and collaborative STEM culture
- Researchers trained in electronics of tomorrow
- Improved public awareness of areas of FLEET science
- Increased student literacy in STEM.

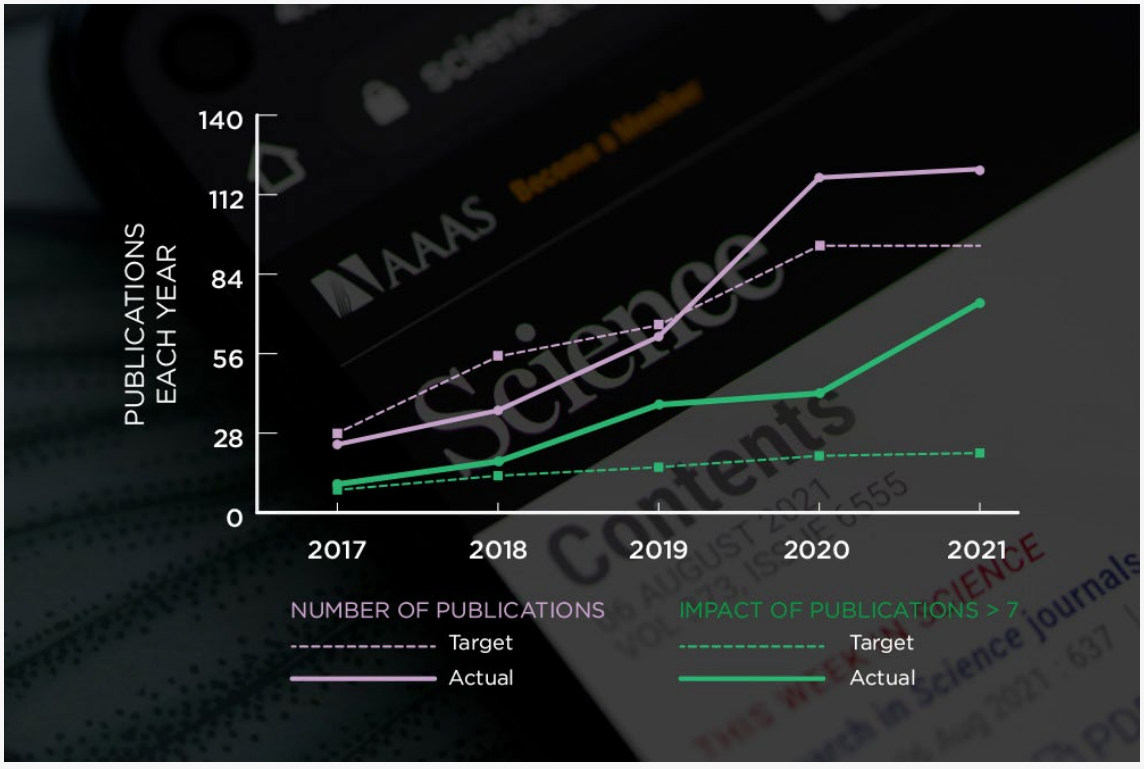


Transformational research

FLEET's transformational research builds on critical mass of Australian strengths

The quality and quantity of FLEET's research outputs is 'on target': the impact of FLEET's 381 peer-reviewed papers from 2017 to 2021 (versus a KPI of 370) is reflected in their high impact factors (55% with IF > 7, well above the KPI of 20%) and their citations in other research (almost 7000 times). In addition, FLEET research has led to seven patent applications and one spin-off company.

Recognition of the quality of FLEET researchers' work is indicated by them having received 16 competitive Australian Research Council (ARC) fellowships (Laureate, Future, DECRA) and six other externally-funded fellowships from 2017 to 2021, exceeding the KPI of eight. FLEET researchers' 146 invited talks at international conferences from 2017 to 2021 meet our KPI of 148 despite the negative impact caused by the pandemic in the past two years.



Research theme 1: Topological materials
FLEET has demonstrated switching a topological insulator via electric fields from topological to conventional insulator, the first such demonstration in any material, and the foundation of a future topological transistor. FLEET's demonstration of topological switching has attracted interest from the international semiconductor audience that led to the inclusion of topological insulator electronics devices in the IEEE International Roadmap for Devices and Systems.

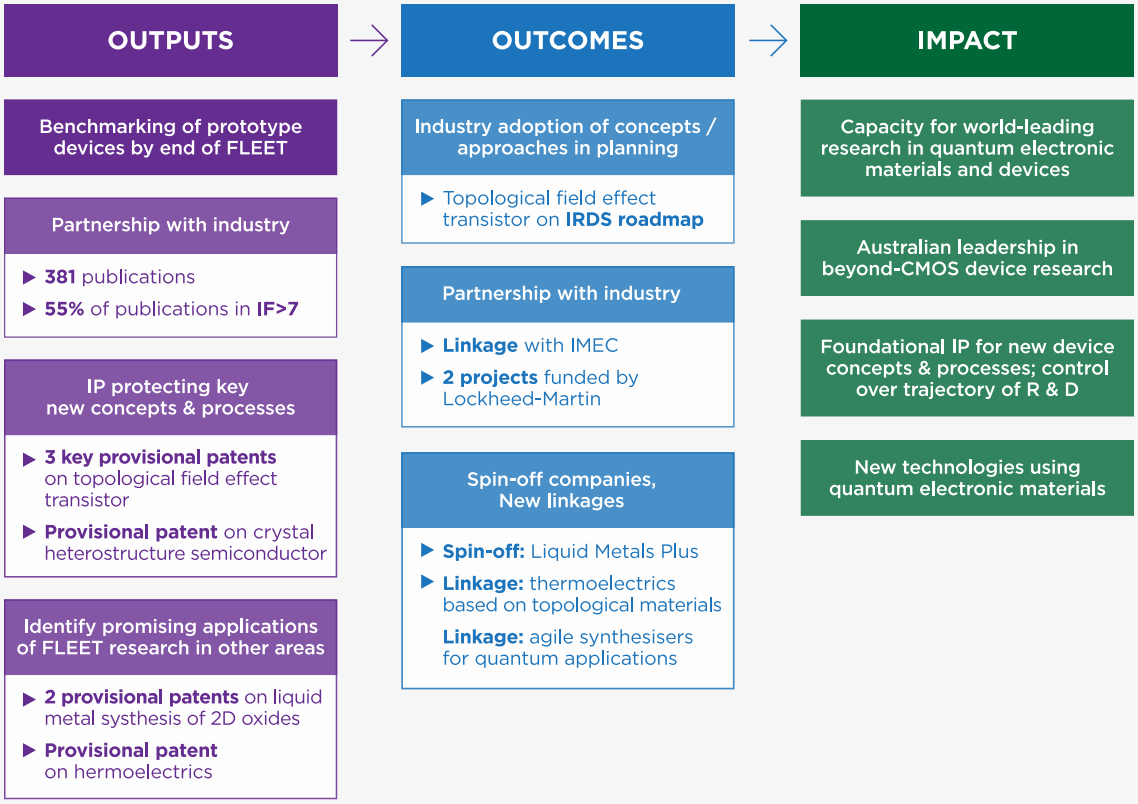
Research theme 2: Exciton superfluids
FLEET is one of few groups worldwide to have demonstrated exciton-polaritons in atomically-thin semiconductors at room temperature, and is a leading contender in global the race to achieve superfluid condensate of exciton-polaritons.

Research theme 3: Light-transformed materials
FLEET has established a unique capacity to dynamically manipulate the electronic structure of materials with light, and is the first and only research group to have made a hybrid condensate at cryogenic temperature.

Enabling technology A: Atomically-thin materials
FLEET has pioneered new atomically-thin topological materials with large bandgaps necessary for room-temperature operation, and is the only group working in 2D materials with the capacity to make large-area atomically-thin devices.

Enabling technology B: Nanodevice fabrication
Potentially transformational research led by FLEET researchers will impact technologies on shorter timescales, including in liquid metals, thermoelectrics, ferroelectrics and hydrogen evolution.

See 2021 progress in each theme and technology in Innovation.



FLEET is linking existing Australian research strengths, and building critical mass with new capacity for interdisciplinary, collaborative approaches.

The growing synergy between research communities at FLEET has seen the percentage of cross-node publications grow from 3.2% (2017) to 16% (2021). Publications involving multiple CIs, AIs, partners and/or nodes make up 61% of all FLEET publications.

The highly interdisciplinary approach within FLEET's large network of investigators and partners includes collaborations between theoreticians and experimentalists, linked liquid-metals materials growth scientists and characterisation specialists, and between optics scientists and condensed-matter physicists.

Significant new, long-lasting Australia research capacity has been developed, including the new ultra-fast laser system at Monash for optical pump-terahertz probe experiments, the expanded ultra-fast laboratory at Swinburne allowing atomically-thin materials study at cryogenic temperatures, and van der Waals hetero-structure fabrication facilities at Monash, UNSW, and RMIT developed via collaboration with FLEET PI James Hone (Columbia University), the technology's inventor.

Strategic partnerships

Working with leading Australian and international research partners

FLEET is developing new networks with major national and international centres and research programs, strengthening research to achieve global competitiveness and recognition for Australian research.

FLEET has more than doubled its links with aligned national and international research institutions, and the Centre's 25 new collaborating organisations include 11 new Partner Investigators and 16 new research associate investigators.

Research relationships are enabled by ensuring a strong presence of Centre personnel at national and international conferences in FLEET fields, seeking out potential research partners through collaborative visits and inviting high-profile researchers in the field to share their work at FLEET colloquia and scientific workshops.

With those international links impacted by Covid in 2020–21, FLEET initiated and co-hosts the transpacific colloquium series, which has linked Australian and North American condensed-matter and cold-atom research communities via 22 colloquia so far.

FLEET has facilitated 25 national and 12 international science conferences and workshops. FLEET has brought three international conferences to Australia for the first time, hosting the International Conferences on 2D Materials and Technologies (2018) and Spontaneous Coherence in Excitonic Systems (2020) and the Asia Pacific Center for Theoretical Physics Workshop on Multiferroics (2021). These showcases for Australia's strength in advanced materials and physics have further cemented connections between FLEET and leading international experts (see Collaboration at FLEET).

Along the way, the Centre's students and early-career researchers (ECRs) have had opportunities to meet and hear from pioneers in the field, including:

- Nobel Laureate Prof Wolfgang Ketterle (FLEET adviser) speaking on Bose-Einstein condensates at the 2017 FLEET workshop
- Nobel Laureate Prof Duncan Haldane on topological matter at the ANU International Physics Summer School in 2018
- Leading international physicists on spin and electron correlation at the Gordon Godfrey workshops at UNSW in 2017 and 2019
- Nobel Laureate Prof Kostya Novoselov (FLEET adviser) on electronic applications of 2D materials at the 2020 FLEET workshop.

As a result of FLEET's network building, collaborative publications (those involving multiple CIs/AIs/PIs/nodes) make up 61% of all FLEET publications, and these publications are 13% more likely to be high impact (IF > 7).

Building human capacity

FLEET is building Australia's scientific capacity by attracting and retaining, from within Australia and abroad, researchers of high international standing as well as the most promising research students.

From its original 64 members, FLEET has built up to 336 high-quality researchers across a range of research areas, training a new generation of leaders at the forefront of modern condensed-matter physics, materials science, and nanotechnology.

FLEET's membership includes two ARC Laureates, eight Future and 11 DECRA Fellows. Of FLEET's higher degree by research (HDR) students, 84% hold an Australian Government Research Training Program Scholarship or receive a university International Postgraduate Research Scholarship.

> FLEET has a clear and systematic strategy to attract and retain the best and brightest minds to join the Centre.
>
> **PROF MICHAEL FUHRER**
> *FLEET Director*

The Centre's multi-institutional and multidisciplinary nature provides unique opportunities for ECRs and students to broaden their horizons and expand their understanding of the research environment.

FLEET is currently training 49 postdoctoral researchers and 56 HDR students. Another 47 postdoctoral researchers and 36 PhD graduates have completed training with FLEET and are now pursuing their own research directions at international research institutions. Among these, 25% are using their STEM skills in industry and government agencies. FLEET celebrates its alumni community, keeping current membership appraised of alums' ongoing career journeys in internal communications (see Lasting impact: FLEET alumni).

Believing that diverse teams do better science, and that an equitable and diverse work environment leads to a more effective team, FLEET is addressing the low representation of women in physics and materials science through recruitment and

career-support measures and by improving the work environment. The Centre's ambitious goal to achieve 30% representation of women at all levels has driven innovative approaches in recruitment, including the Women in FLEET Fellowship, the first of its kind in ARC Centres of Excellence (see 2021 progress and details in Equity).

FLEET support for researchers with caring responsibilities has included providing onsite childcare at Centre-organised events so that members don't have to compromise between research training opportunities and their carer's responsibilities.

In addition to improving the gender balance, FLEET initiatives towards increased participation in STEM by under-represented groups include the new Diversity in FLEET Fellowships.

FLEET provides high-quality postgraduate and postdoctoral training environments for the next generation of researchers.

Knowing that most STEM PhD graduates end up in careers outside academia, FLEET helps students develop a diverse skills base to enhance their future job opportunities, ensuring readiness for whichever career path they pursue.

Members have access to a tailored education and training program that emphasises not only technical skills but also transferable skills in all stages of members' career development, building future leaders in science and technology from academia to industry, in Australia and internationally.

The Centre's 50 workshops have offered a range of different research and professional development opportunities, from advanced physics to building skills in communication, presenting scientific results or creating visuals to enhance the impact of their research outputs.

Notable examples include the Summer School at the ANU node, which offered an intensive course in topological properties of matter for incoming HDR students, and programs such as the Idea Factory (run in collaboration with the ARC Centre for Engineered Quantum Technology – EQUS) and FLEET's Young Researchers Forum (YouRforum) that provide training in broader transferable skills required to thrive within and outside of academic research.

FLEET provides mentoring to personnel across all cohorts with regard to career planning and advancement, equity and diversity, professional development, entrepreneurship, and research leadership skills. Mentoring models include participation in the Centre's governance committees, group mentoring via training sessions, and individual goal-oriented mentoring through four tailored mentoring programs: for ECRs, industry, academia, and women.

Since the program launch, 84 mentorship pairs have been formed. Currently, 32% of students, 54% of research fellows, 67% of associate investigators, 12% of partner investigators and 65% of chief investigators are mentees or mentors in at least one of the four FLEET mentoring programs. (See Education).

FLEET offers Australian researchers opportunities to work on large-scale problems over longer periods of time.

The challenge of energy consumption in ICT is a pressing global issue, and will be the focus of significant research over decadal timescales.

The Semiconductor Industry Association Decadal Plan (January 2021) names the looming energy bottleneck on future computing growth as one of five 'seismic shifts' in the industry and calls for an investment of $750M per annum over 10 years in basic research to identify solutions.

Early investment in FLEET puts Australia at the forefront of this research effort, and positions FLEET's researchers for ongoing global contributions.

The development of energy-efficient computing technology will employ investigators across multiple disciplines, with theory and experiment, discovering new materials, elucidating new properties, and building and benchmarking prototype devices.

Long timescales will be required to integrate all parts of the approach and iterate the cycle of theoretical prediction to materials synthesis to characterisation to refinement of theoretical models and concepts to prediction of better materials and devices.

The broad network of experts established by FLEET establishes new capacity for ongoing, world-leading electronic materials research in Australia. Large networks with long timescales will be essential for producing transformational outcomes.

FLEET's capacity building has also galvanised the Australian research community to take the lead in electronic materials research more broadly. It opens new windows of opportunities for further scientific advancement of FLEET's discoveries, commercial development of FLEET's patents and intellectual property, and new research programs that have stemmed from capacity and relationships built through FLEET.

A compelling example of this value gain is additional research funding secured by members: Between 2017 and 2021, FLEET researchers have won over $33M in grant value from other ARC schemes, industry grants and Australian and US government funding.

Wide community impact

FLEET's impact on the wider community leverages interaction with education institutions, government, industry and the private and non- profit sectors.

FLEET is building Australia's scientific capacity by attracting and retaining, from within Australia and abroad, researchers of high international standing as well as the most promising research students.

The Centre shares the responsibility to support students and teachers to increase participation rates in STEM by linking the science teaching curriculum to cutting-edge research.

FLEET is the only Centre of Excellence asking all of its members to contribute 20 hours of outreach a year; the additional benefit is that it is valuable science-communication practice for Centre members. With almost 6000 hours spent on 515 outreach activities to date, FLEET members have reached more than 900 teachers, 21,000 students and over 33,000 members of the public.

Accessible science resources for school-age kids and parents include 89 home science demos sparking interest and curiosity in STEM in young children. These experiments have had over 100,000 views to date.

FLEET members have visited and hosted more than 80 school tours through FLEET laboratories, engaging students with relevant issues such as energy use in computing, how transistors work, and the new fields of science studied at FLEET. In a fruitful partnership with the Monash Tech School, FLEET has hosted lab tours providing hands-on science experiences for over 1200 secondary students and counting. In addition, virtual tours of FLEET labs were also developed to engage with students from remote schools, who do not get the opportunity to visit urban universities.

FLEET's superconducting Mobius track is one of several innovative games and physical demonstrations developed at FLEET. The prototype is at Melbourne's Scienceworks museum and two tracks are used as outreach tools by FLEET nodes.

FLEET's Year 10 elective Future Electronics course, delivered in partnership with John Monash Science School (JMSS) each year since 2019, is the only school unit in Australia covering the history of semiconductors, computing and Moore's Law, and building up from quantum fundamentals to the physics of advanced materials and digital operations. Surveying of past students conducted in 2021 confirms the unit's impact in persuading students, particularly girls, to consider a future in physics (see case study).

FLEET researchers have participated in major community events such as Melbourne Knowledge Week (2018, 2019 and 2021) and Sydney Science Festival (2019). At the latter event, members engaged with over 9000 school students, ranging from preschool to secondary level, in just nine days.

FLEET members have briefed politicians and policymakers at the Victorian and NSW Energy ministries and the Victorian Department of Jobs, Precincts and Regions; hosted visits from Education Minister Simon Birmingham, ARC CEO Sue Thomas, NSW MP Paul Scully, and Melbourne MP and Greens Science and Energy spokesperson Dr Adam Bandt; and engaged with local MPs as part of Science in Parliament.

FLEET researchers have developed important semiconductor industry links including with global foundry Taiwan Semiconductor Manufacturing Company. The Centre worked with the Institute of Electrical and Electronics Engineers and provided consultation to include topological electronics in the IEEE International Roadmap for Devices and Systems.

EQUITY AT FLEET

In 2021, policies promoting equity and diversity have been broadened to a wider focus than gender alone

EQUITY AND DIVERSITY

CULTURAL BACKGROUNDS

WOMEN AND LEADERSHIP AUSTRALIA SCHOLARSHIPS RECEIVED

WOMEN IN FLEET HONOURS SCHOLARSHIPS OFFERED

FLEET WRITE-UP SCHOLARSHIPS OFFERED

25% **WOMEN IN FLEET** (OUT OF 221 CENTRE MEMBERS)

23% **WOMEN RESEARCH STUDENTS AND ASSOCIATES**

33% **WOMEN EARLY CAREER RESEARCHERS**

CHIEF INVESTIGATORS

PARTNER INVESTIGATORS

SCIENTIFIC ASSOCIATE INVESTIGATORS

RESEARCH FELLOWS

STUDENTS AND RESEARCH ASSOCIATES

ADVISORS AND LIAISONS

CENTRE BUSINESS TEAM

Note data unavailable: indigenous members, people with disability

Equity and diversity at FLEET

FLEET's steps to improve women's representation in physics, within the Centre and more widely, have also expanded to encompass wider definitions of diversity.

CASE STUDY

Listening to our people: Centre-wide members' survey

Read our case study

Diverse teams do better science. By increasing the diversity of our own team, and Australian science more widely, we are both doing what's fair and improving our capacity to do great research.

In 2021, FLEET efforts to improve gender equity (see Women in FLEET) have been expanded to encompass wider definitions of diversity, increasing the representation of people from diverse backgrounds, and circumstances including Indigenous, LGBTIQA+, living with a disability or caring for a person with a disability, refugee, low-socioeconomic backgrounds. See more about FLEET's new Diversity Fellowships and scholarships , the first such postdoctoral research fellowships in Australia.

As well as increasing the representation of people from all minority groups in STEM, FLEET's main focusses in 2021 have been supporting our people through Covid-19, and further increasing the number of women at investigator levels.

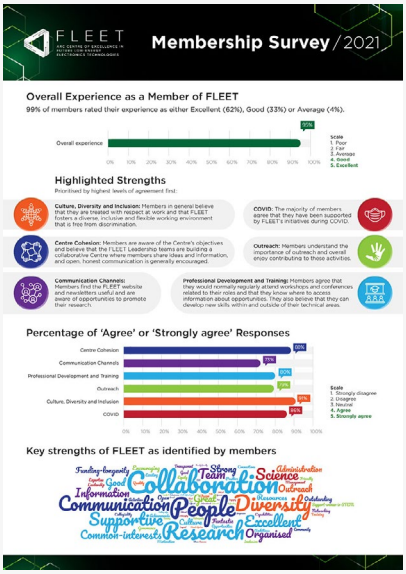
FLEET has continued improvement in representation of women at higher levels, increasing female representation among the Centre's advisers and liaisons who guide FLEET management and scientific directions from 21% in 2019 to 29% now. In addition, three new female scientific associate investigators were added to FLEET in 2021.

FLEET's Women in FLEET Fellowships and strategic grants have allowed the Centre to increase the percentage of women at the associate investigator level to 38%, which is above the average in physics. At 25% of all members, the Centre is close to our ambitious target of 30% women at all levels but still has work to do.

FLEET initiatives support researchers with caring responsibilities and provide on-site childcare at Centre-organised events, so members don't have to compromise between research training opportunities and their responsibilities as a carer.

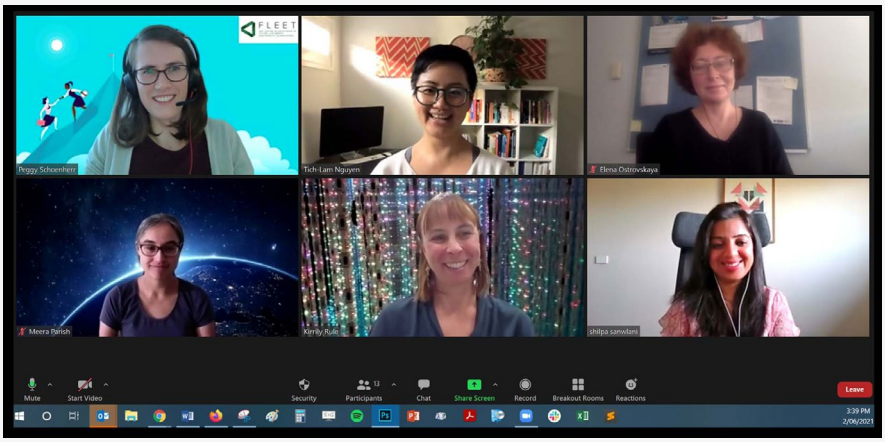
Such policies have lasting impact, making it 'more normal' for carers to attend scientific workshops.

Culture, Diversity and Inclusion



In particular, fixing the infamous 'leaky pipeline' regarding gender equity in science involves both retaining female researchers and recruiting more. And while Centre initiatives have helped us retain women in 2020–21 (with the help of Women in FLEET scholarships and Fellowships), Covid-19 has continued to restrict our ability to recruit.

In addition to recruitment and career-support measures, FLEET has addressed low representation of women in physics and materials science by improving the work environment, which benefits all members.



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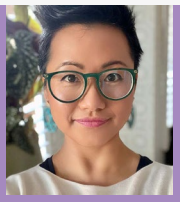
Such policies have lasting impact, making it 'more normal' for carers to attend scientific workshops.

> FLEET's family-friendly workshops are a real hit. There is a totally different vibe from a 'regular' conference and it really helps people connect on a more personal and human level.
>
> **FLEET MEMBER SURVEY**

EQUITY AND DIVERSITY HIGHLIGHTS IN 2021

- Adding Diversity in FLEET scholarships and Fellowships to Women in FLEET initiatives, aimed at increasing representation of people from diverse backgrounds and circumstances under-represented in Australian STEM
- Training our people to recognise and respond to unacceptable behaviours in the workplace
- Providing access to professional counselling services through an Employee Assistance Program
- Continuing to support our members through Covid, via write-up scholarships and other initiatives
- Confirming our influence on girls to considering studying physics in surveys following the FLEET–JMSS (John Monash Science School) Future Electronics unit (see **case study**).
  Facilitate communication

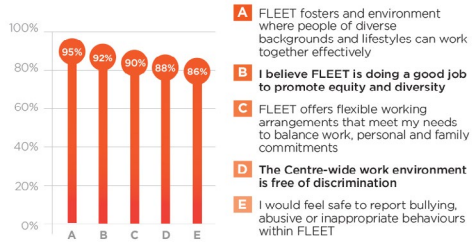
FLEET's investment in its people is paying dividends. Centre cohesion, Centre culture, diversity and inclusion have the highest levels of agreement in the all-member survey conducted by FLEET in early 2021 (see **case study**).



One of my highlights in 2021 was receiving personal feedback from members expressing thanks for the little things FLEET did to support them through Covid.

DR TICH-LAM NGUYEN
Centre COO

Culture, Diversity and Inclusion



92% of participants said they believe FLEET is doing a good job with respect to equity, in the Centre's 2021 Centre-wide survey

- Help increase diversity in STEM in Australia
- Provide models for more-inclusive research collaboration

As a Centre of Excellence, FLEET has an opportunity to 'change the culture' and establish new best practices that have an effect beyond the Centre.

For example, after attending FLEET's family-friendly all-Centre meetings, several visiting partners have returned to their own organisation to encourage similar models. FLEET has worked with organisers towards providing sponsor support for family-friendly assistance at a number of external events. FLEET's Women in FLEET and Diversity in FLEET fellowships are being looked at by other research institutions.

RESPONSES TO COVID

Like all organisations in 2020–21, FLEET made significant changes in response to Covid, many of which will be adopted permanently. These include more flexible working arrangements, such as working from home, and less academic travel, which adversely effects both family life and the environment.

Many post-Covid initiatives have helped FLEET design new best practices for Centre collaboration, communication, education, engagement, and equity programs.

FLEET's 2021 'Pandemic and you' survey explored how our members were being impacted by Covid-19. Results showed that while the impacts of the pandemic were varied, they fell heaviest on caregivers and those in early in their career. As a result, the Centre has since:

- Created PhD write-up scholarships for students affected by the restrictions
- Offered several PhD candidature and postdoctoral contract extensions
- Encouraged regular check-ins from supervisors
- Supported eligible postdocs whose contracts were ending where possible
- Reduced the Centre's KPI contribution expectations from members
- Engaged with Employee Assistance Program Services to offer professional counselling services for FLEET members
- Maintained international links via ongoing trans-Pacific and trans-Tasman seminar series, and Asia-Pacific multiferroic conference (see case study Maintaining international research connections).

> My uni gave me a grant to buy equipment to set up a home office. My supervisor helped me to develop a theory-based project during the lockdown in Melbourne. The business team helped me access a database I didn't have access to at my home uni.
>
> **FLEET MEMBER SURVEY RESPONSE**

Even prior to Covid, FLEET's annual internal surveys had shown that the mental health and work-life balance of many young researchers could be put at jeopardy by work stresses. The Centre's 2020 and 2021 surveys confirmed that this risk had intensified.

FLEET's concrete initiatives above have assisted in taking some work-related pressure off our people, but this is only part of the story. People are also affected by external issues such as isolation from friends and family, and fears concerning health and career.

Over 90% of respondents to a 2019 FLEET survey were aware of opportunities FLEET provides to help make it easier to balance work and family life.

FLEET has also sought to mitigate isolation challenges by offering an Employee Assistance Program where members can seek help from professional psychologists when they need to. Three members have accessed this service to date.

> There are real opportunities here to do things better. There's a nice confluence of saving energy (less travel) and advancing equity (various kinds of flexible work arrangements are now on the table). FLEET also has an opportunity to 'change the culture', and establish new best practices.
>
> **PROF MICHAEL FUHRER**
> *FLEET Director*

To help FLEET become more aware of unconscious bias and other barriers to cultural and gender diversity and inclusion, each year every FLEET member must attend at least one training workshop or training session in equity, diversity and inclusion.

EQUITY-RELATED TRAINING

Members may undertake any training and development opportunity of their choice, including face-to-face sessions, webinars or online modules. We believe that letting individuals select training that matches their personal situation and areas of interest will offset some of the 'equity fatigue' that can sometimes accompany mandatory training.

The FLEET website, intranet and newsletter provide links to resources and opportunities available at individual nodes, as well as those provided by FLEET partner the Diversity Council Australia (DCA), which provides a wide toolkit of knowledge programs, research, practical tools and events.

Centralised equity training in 2021 included the panel 'What makes women strong in what they do?' organised by FLEET Research Fellow Dr Peggy Schoenherr and featuring five FLEET women sharing their personal experiences. FLEET also ran Active bystander training, in conjunction with Monash University's Respectful Communities unit.

FLEET Associate Investigator Dr Peggy Schoenherr

To help members choose the training that best suits them, FLEET promotes Diversity Council Australia events. In 2021 they included a 'masterclass' on identifying and eliminating sexual harassment, a workshop on how to build workplace inclusion, and an information session on the Inclusion@Work Index.

FLEET members also participated in the following equity-and-diversity related training:

- Roses Among Thorns: Empowering women leaders in STEM and entrepreneurship organised by the Postgraduate Council UNSW
- An indigenous engagement workshop, organised by the University of Queensland School of Mathematics and Physics
- 'Women in Science Network: Science Communication Panel', organised by the University of Melbourne
- LGBTIQA+ Awareness and Empowering Allies Training.

WOMEN IN FLEET

The Women in FLEET Fellowships were introduced in 2019, to support Centre efforts to increase the percentage of women at early-career researcher (ECR) and associate investigator levels to above the relatively-low average in fields such as physics, engineering and materials science.

The Fellowships will have a significant impact on both the future careers of these women as well as on the future workforce. Two of the three Women in FLEET Fellows have secured academic positions at top research institutions in Europe.

IMPACT

Individual highlights for women in FLEET in 2021 include:

- One Fellow securing a tenure-track academic position in the Netherlands
- An ECR winning a prestigious research fellowship in Spain
- COO winning a scholarship from Women in Leadership Development, WILD for STEM, to train with the Australian Institute of Company Directors
- Four women in FLEET winning scholarships to participate in Women and Leadership Australia's Leading Edge program.

With our Women in FLEET Fellowships, the Strategic Seed Grant Scheme and other strategies, the Centre has achieved 25% representation of women overall.

In addition, Women in FLEET scholarships for higher-degree by research students assist ECRs at the beginning of their science career.

An important aspect of Centres of Excellence is their capacity to change the culture of the way science is done. Learnings from the Fellowship design and implementation process have been shared with other research centres via a white paper.

Redressing historical disadvantages for women in physics provides many complex challenges, and our actions must cut across all of FLEET's strategies and policies. Internal surveying of experiences and attitudes (see case study) helps maximise the chance of success for these changes.

> Centres of Excellence can exhibit a high level of autonomy. Making change in an institution as big as a whole university can be glacial. But centres have demonstrated they can test ideas that the university may, over time, also be able to embrace.

DR MEGAN POWER
Writing for ARC

DID you KNOW

Women account for only 29% of Australia's STEM research workforce

Supporting diversity

Improving diversity in science beyond just gender.

CASE STUDY

In 2021, FLEET's steps to improve women's representation in physics have also expanded to wider definitions of diversity.

To maximise the effectiveness of our research team, and to improve diversity in Australian science, FLEET has added new Diversity Fellowships to complement the existing Women in FLEET Fellowships. This opens up our fellowships to a wider range of applicants from under-represented groups in Australian STEM.

Diversity in FLEET Fellowships are open to individuals from any group that is under-represented in Australian STEM, or who have experienced uncommon hardship. Examples include, but are not limited to applicants who:

- Identify as Aboriginal and/or Torres Strait Islander
- Have a disability or who cares for a person with a disability
- Identify as LGBTIQA+
- Are from a regional / remote area
- Are from a disadvantaged or low socio-economic background
- Are from a refugee background
- Have experienced uncommon hardship, which could include, but is not limited to experiences of domestic violence or debilitating health issues.

Both categories of Fellowship allow for improved flexibility in the location and type of position on offer. Rather than advertising highly-focused research roles with specific expertise criteria, which is standard in scientific recruiting and contributes to maintaining the status quo in gender balance and diversity.

Instead, Women in FLEET and Diversity Fellowships allow for applications from talented individuals whose research interests align with any research areas within FLEET, giving applicants the choice to nominate investigators they want to work with. The new Fellows may be experimental or theoretical, physicists, chemists or engineers, located at any of seven universities. The flexibility of offering whichever field suits the best applicants available allows the widest choice of applicants, ensuring FLEET will hire the best possible candidates.

The effectiveness of this broader search in allowing FLEET to find excellent researchers who may have been missed in previous, narrowly-targeted searches was confirmed by the remarkable increase in applications for previous Women in FLEET Fellowships. In the first round, FLEET received almost 70 applications – more women than the combined total from 14 previous, more-targeted searches.

Fellowships are available at Monash University, UNSW, RMIT University, Swinburne University of Technology, ANU, the University of Queensland, or the University of Wollongong.

In addition to Fellowships for postdocs, Diversity in FLEET scholarships are aimed at assisting higher degree by research students at the beginning of their science career.

Planning and implementing the Diversity in FLEET fellowships was a very significant project for members of the Centre's Equity and Diversity Committee in 2021, including guidance from leaders in the Women in STEM Australia network.

The Diversity in FLEET Fellowship is the first of its kind. There are scholarships and small grants to support people in minority groups in STEM but not a postdoctoral fellowship.

PROF JEFF DAVIS
FLEET Equity and Diversity Chair

More at FLEET.org.au

CASE STUDY

FLEET Acknowledgement of Country

Read our case study

Listening to our people

FLEET's strengths are Collaboration, Research, People, Diversity and Communication (survey).

CASE STUDY

A comprehensive FLEET membership survey in Q1 2021 gathered feedback from FLEET students, postdocs and investigators, as well as FLEET alums.

- 95% have good or excellent experience working in FLEET
- 90% believe FLEET is doing a good job to promote equity and diversity
- 92% agree or strongly agree FLEET fosters an environment where people of diverse backgrounds and lifestyles can work together effectively.

When asked to state three key strengths of the Centre, the top five words members used were collaboration, research, people, diversity and communication.

Responses, which came from 55% of FLEET membership, offered strong insights into what works and what doesn't, right across the Centre. While it is great that 95% of respondents rated their experience at FLEET as 'Good' or 'Excellent', we also received clear feedback on areas where FLEET can improve. Centre management and committees are working to implement responses to that feedback in future initiatives and programs.

Highlighted strengths of FLEET are:

- Culture, Diversity and Inclusion: Members believe that they are treated with respect at work and that FLEET fosters a diverse, inclusive and flexible working environment that is free from discrimination.
- Centre Cohesion: Members are aware of the Centre's objectives and believe that the FLEET Leadership teams are building a collaborative Centre where members share ideas and information, and open, honest communication is generally encouraged.
- Covid: The majority of members agree that they have been supported by FLEET's initiatives during Covid.
- Professional Development and Training: Members agree that they would normally regularly attend workshops and conferences related to their roles and that they know where to access information about opportunities. They also believe that they can develop new skills within and outside their technical areas.

- Outreach: Members understand the importance of outreach and overall enjoy contributing to these activities.
- Communication Channels: Members find the FLEET website and newsletters useful and are aware of opportunities to promote their research.
- Using an external survey provider (Leaderskill) maintained independence and confidentiality throughout the survey process.

Changes implemented by FLEET based on survey findings included:

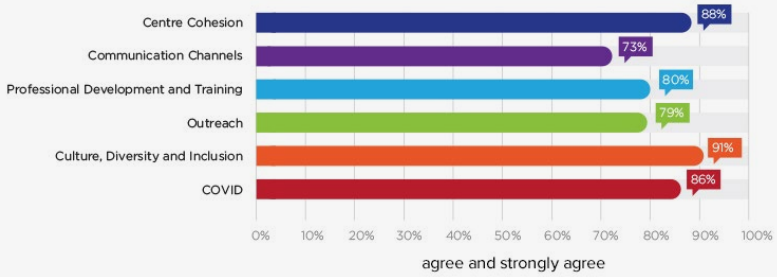
- Facilitated training workshop to identify inappropriate workplace behaviours
- Added an 'emergency phone' communication channel, available at the click of a button on the FLEET intranet, so that all members could ask for help quickly, if needed
- Reduced the number of internal seminars (see Collaboration)
- Fine-tuned internal communications to reduce email clutter (see Internal Communication).

Since 2018, annual FLEET surveys have examined the quality and impact of current initiatives and identified best ways to support members. Surveys are voluntary and anonymous, and they have obtained an average response rate of 40%. Other surveys ensuring the Centre is serving the needs of its members include:

- Pandemic survey in 2020 exploring how members were being impacted by Covid-19 and how the Centre could help (see Responses to Covid)
- Standalone equity surveys each year except 2021
- ECR Training Working Group survey 2021.

Outside these surveys, members can provide feedback or raise any matter that needs FLEET management attention via the FLEET intranet and KPI portal.

Areas of strength at FLEET, as identified by members*



FLEET's key strengths*

FLEET Centre-wide members' survey 2021

> I think formal communication within FLEET improved over the course of the pandemic. People were much more open to chatting with others, and more receptive to sharing their personal lives with each other.
>
> **FLEET MEMBER SURVEY RESPONSE**

View survey results

Acknowledgement of Country

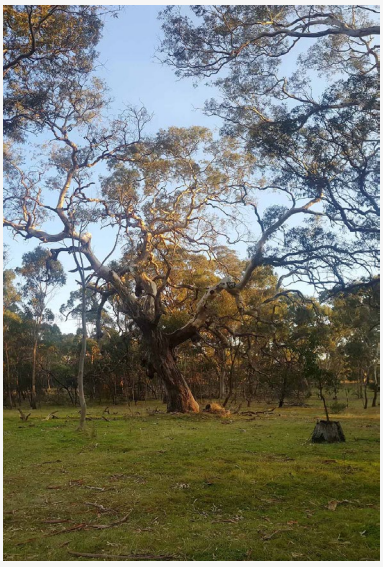
Acknowledging those on whose Country we live and work.

CASE STUDY

FLEET guidelines encouraging appropriate, genuine Acknowledgement of Country have been put into use at Centre events in 2021.

FLEET values the contributions of our diverse members, spanning 27 cultural backgrounds. In particular, we acknowledge and respect the Aboriginal and Torres Strait Islander peoples as First Australians. We celebrate the uniqueness of knowledges, cultures, science, histories and languages that have been created and shared for at least 65,000 years.

FLEET members are encouraged to consistently acknowledge the Traditional Custodians of Country at the beginning of any formal functions, meetings and forums they host. This includes Zoom sessions and online events where the local moderator should offer the acknowledgement, and in documents such as the Centre annual report and PhD theses.



Among the lands on which FLEET operates are those of the Wurundjeri people of the Kulin nation (northwestern Melbourne region).

Members are encouraged to say this in their own words. FLEET does not consider a script that members are required to read out to be the ideal (i.e. the most compelling or the most sincere) way to acknowledge traditional ownership.

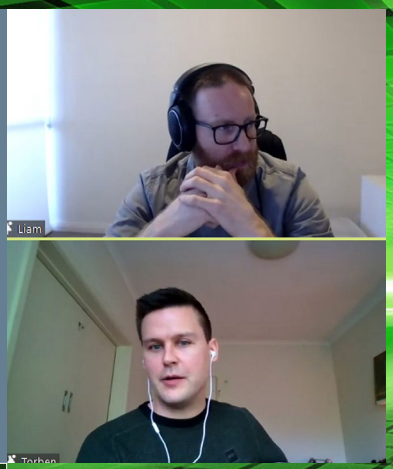
Instead, in 2021 FLEET developed acknowledgement guidelines that encourage members to do their own research ('we are scientists, after all!') and then to write their, more genuine acknowledgement.

However, we also know that many feel uncomfortable the first few times they acknowledge Country. We therefore also provide members with an 'example script', in the hope that as they gain confidence, they will be able to build on this and work towards a more personal acknowledgement.

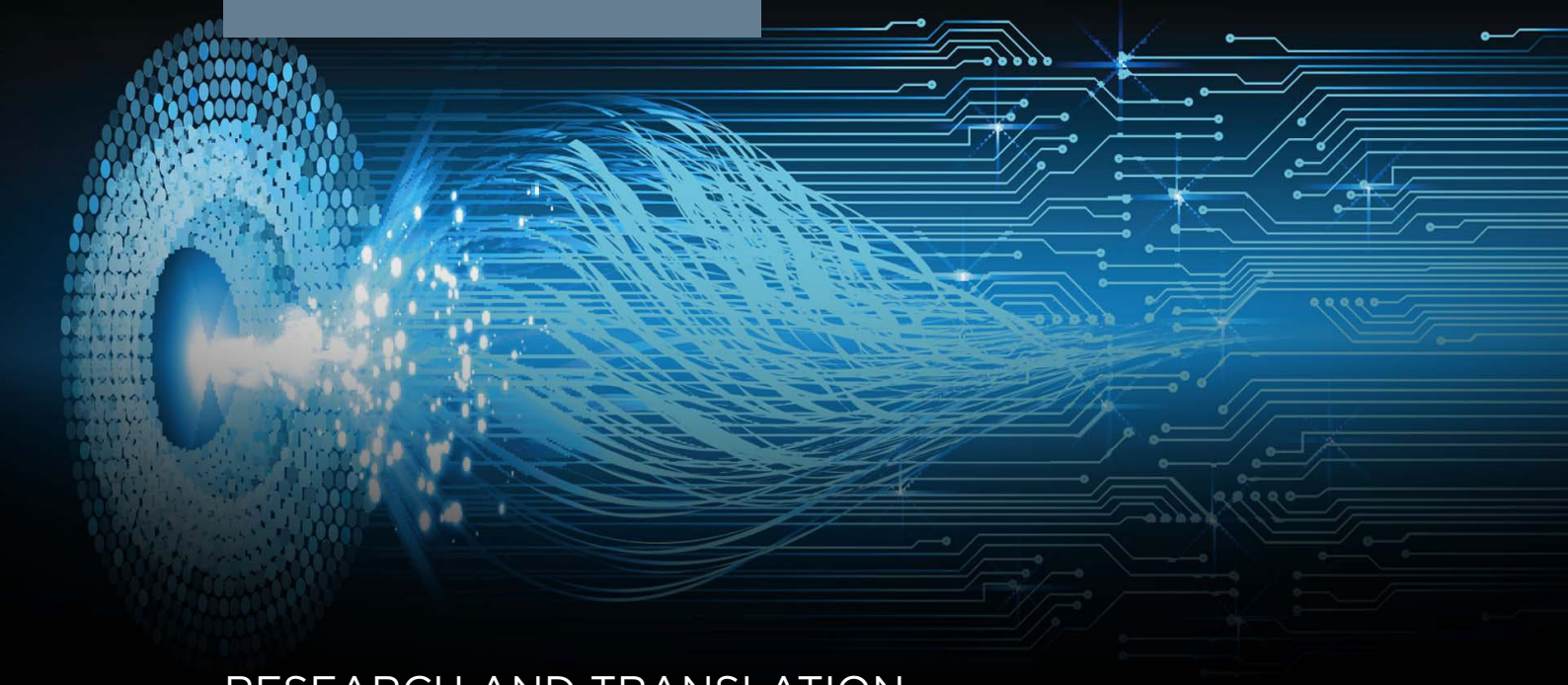
Read more
FLEET.org.au

RESEARCH TRANSLATION

- Key data
- Research translation
- Translation program
- End-user engagement



FLEET is ensuring sustainable translation of research outcomes



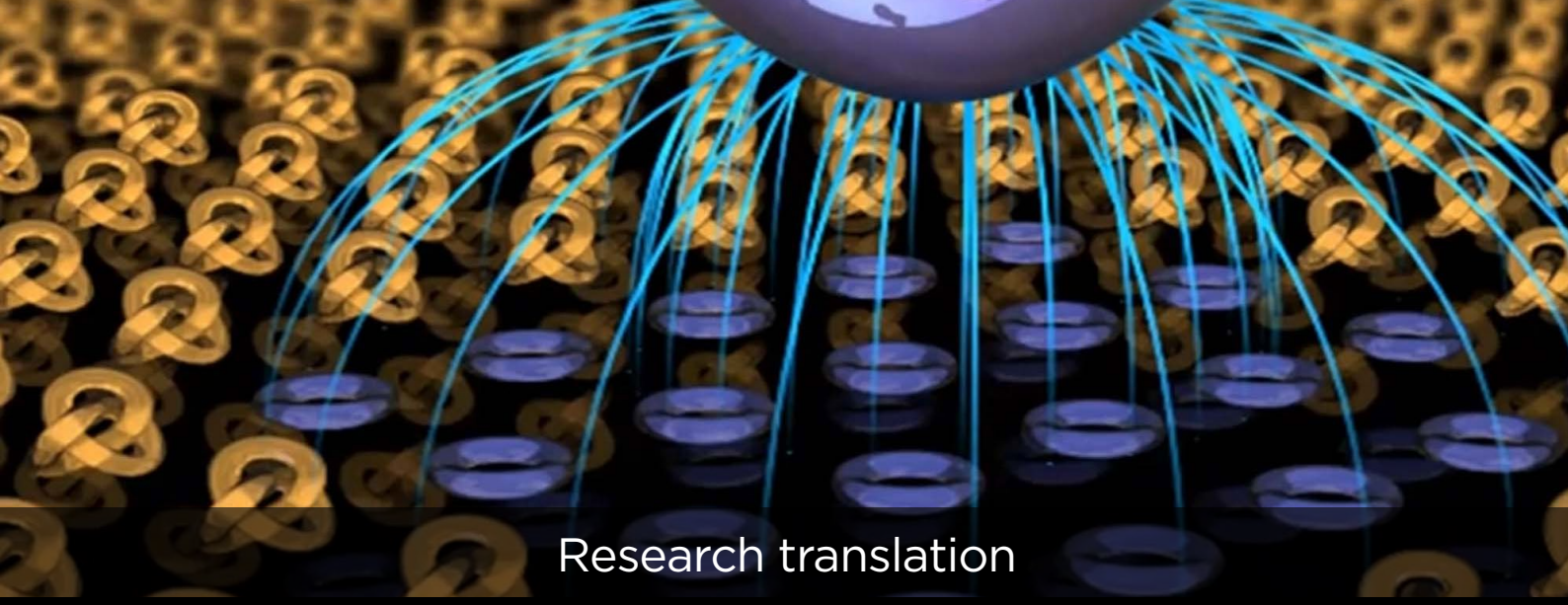
RESEARCH AND TRANSLATION

2
PROVISIONAL PATENTS

5
INDUSTRY BRIEFINGS

3
ARC LINKAGE PROJECTS

4
LINKAGE INDUSTRY PARTNERS



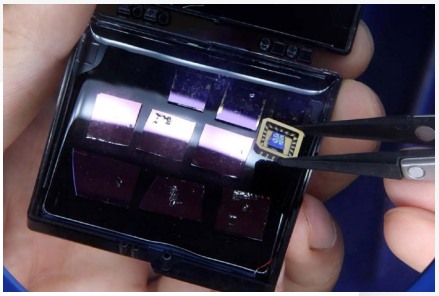
Research translation

FLEET is ensuring sustainable translation of research outcomes.

With a goal to help transform Australia's electronic technologies, FLEET welcomes partnerships with industry organisations. FLEET is actively building links with partners interested in novel electronic devices and systems, working towards research translation outcomes.

ENGAGING WITH INDUSTRY

- Progress towards this important goal in 2021 included:
- Beginning Linkage projects to develop hole spin quantum bits in industrially fabricated silicon chips between FLEET-UNSW team (Hamilton and Culcer) and international R&D organisation, Interuniversity Microelectronics Centre (IMEC)
- Launching Linkage project between MOG Labs and FLEET-Monash University (Helmerson) to develop agile synthesisers for quantum computing, simulation and sensing
- Starting Linkage project between Australian companies and FLEET's University of Wollongong node to develop functional materials for superior thermoelectric applications
- Lodging two provisional patents: Negative-capacitance topological quantum field-effect transistor, and crystal hetero-structure semiconductor device. See more below.
- Launching new FLEET industry-engagement seminar series
- Briefing the world-leading semiconductor fabricator Taiwan Semiconductor Manufacturing Company (TSMC) about FLEET's research mission and progress
- Giving technical briefings to Oxford Instruments (UK), commercial quantum software company HQS Quantum Simulations (Germany), semiconductor firm Ferroelectric Memory Company (German), and venture capital firm Businessizer AS (Norway)
- Offering training to FLEET members to raise awareness of industry working environment and prepare them for diverse future careers (see Training)



CASE STUDY

New FLEET Translation Program to shepherd scientific discovery towards commercialisation

Read our case study

PATENTS AND STARTUP PROGRESS

FLEET is committed to boosting the Australian research and development sector and making opportunities to create high-value intellectual property for transforming electronic technologies by focusing on developing advanced structures that will offer dissipationless electronics.

Two new provisional patents were lodged in 2021:

- Negative capacitance topological quantum field effect transistor (TQFET), showing that a topological transistor can switch with lower voltage than a conventional transistor (Fuhrer)
- Crystal hetero-structure semiconductor device and fabrication process (Hamilton, Klochan, DQ Wang, Ashlea-Alava)

The technology covered by our new high-conductivity crystal hetero-structure patent will allow devices optimised for lower noise and higher frequency operations, improving device performance in applications such as mobile and radio communications, radar and satellite communications.

DAISY QINGWEN WANG
Co-patent holder FLEET Research Fellow

FLEET's mission is to enable continuing growth of computing without that growth being throttled by the availability and costs of energy. We do this by developing a new transistor that can switch at lower energy. Along the way, we are creating new IP on material fabrication, processes and theory/modelling methods.

Suites of important quantum materials IP created within FLEET will serve as the basis for establishing spin-off companies.

FLEET members hold seven patents and FLEET investigators Prof Kourosh Kalantar-zadeh (UNSW) and Dr Torben Daeneke (RMIT University), together with Dr Dorna Esrafilzadeh (UNSW), established a successful startup (LM Plus) in 2020, launched in April 2021.

FLEET's capacity building has also galvanised the Australian research community to take the lead in electronic materials research more broadly. It opens new windows of opportunities for further scientific advancement of FLEET's discoveries, commercial development of FLEET's patents and intellectual property, and new research programs that have stemmed from capacity and relationships built through FLEET. A compelling example of this value gain is additional research funding secured by members: Between 2017 and 2021, FLEET researchers have won over $33M in grant value from other ARC schemes, industry grants and Australian and US government funding.

IN 2022 FLEET WILL...

- Continue the industry seminar series, starting with Dr Carlos Diaz (TSMC)
- Implement the **FLEET Research Translation Program** with a target to fund at least two projects
- Continue FLEET internal training to develop transferable skills for industry and other career paths, including intellectual property, commercialisation and research translation
- Continue to pursue industry internship opportunities for FLEET graduates.

> I really want to see how my work can be related to industrial research.
>
> **FLEET MEMBER SURVEY RESPONSE**

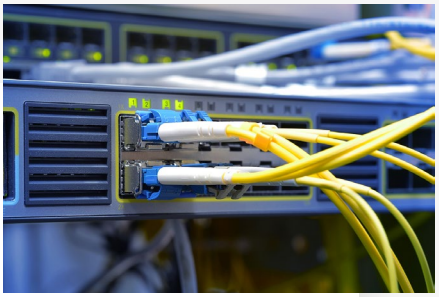
FLEET RESEARCH AND INTELLECTUAL PROPERTY STRATEGY

FOCUS ON DEVICE LEVEL	FUNDAMENTALLY NEW CONCEPTS	TECHNOLOGY READINESS LEVEL 1-3	OUTCOMES	IMPACT
A NEW SWITCH A transistor with lower switch energy	Topological materials Excitonic superfluids	New materials New concepts New processes	Benchmarking of prototype devices by end of FLEET IP protecting key new concepts & processes Industry adoption of concepts / approaches in planning Partnerships with industry Identifying promising applications of FLEET research in other technology areas	Capacity for world-leading research in quantum electronic materials and devices Australian leadership in beyond-CMOS device research Foundational IP for new device concepts & processes; control over trajectory of R & D

CASE STUDY

Engaging with end users: Melbourne Computer Club

Read out case study



INDUSTRY-ENGAGEMENT SEMINAR SERIES

In 2021 FLEET initiated a series of industry-engagement seminars, held roughly every three months, that aim to provide insights on university–industry collaborations, commercialisation of Australian research technology, the semiconductor industry in Australia and overseas, and alternative career paths for STEM PhD graduates.

Presentations in this first year included:

- Dr Erol Harvey (Aikenhead Centre of Medical Discovery, Bionics Institute Australia, miniFAB) speaking about research commercialisation and entrepreneuship
- Dr Steve Duvall (Silanna Semiconductor) on the process of commercialising semiconductor science and collaborating with semiconductor companies
- Dr Sarah Jaber (University Industry Innovation Network) sharing insights on university-industry engagement, the world of consultancy, and employable skills that STEM researchers can transfer to careers outside academia
- Dr Laura Faulconer (Antler), presenting a venture capital-backed startup career pathway, spotlighting initiation of selected Australian/NZ high growth deep-tech startups, the scientists and engineers that are building these companies, and the investors backing them.

GETTING FLEET NEWS IN INDUSTRY MEDIA

In recent years FLEET has significantly increased placement of FLEET news in industry-relevant media by pressing researchers to identify possible industry 'hooks' in each story. In 2021 FLEET science featured in TechXplore, with over 10,000 views, in semiconductor industry online and magazine news, in electronics news, in IEEE Spectrum, and in the Materials Australia magazine, which provides technical and materials support to engineering, manufacturing and research industries.

Along with Centre press releases, these articles have been effective in alerting Australian and international industry to FLEET work, resulting in many industry contacts and a handful of (non-FLEET) concrete contracts being signed.

The Centre has also seen significant value in a strong presence on professional network LinkedIn, and at the end-of-year meeting, launched a campaign to improve members' presence on that platform.

In particular, FLEET Associate Investigator Dr Torben Daeneke (RMIT) reports over 20 contacts coming from people having seen his team's work on LinkedIn, or seeing his work being reported elsewhere and then locating him via LinkedIn.

> LinkedIn combined with effective press releases works well. Two of the many contacts I've received via FLEET press releases and LinkedIn have then led to signed partnerships, seeing $2.85 million in external funding being put into research projects at RMIT, and enabling the hiring of new students (i.e. more science is being done!)

DR TORBEN DAENEKE
FLEET Associate Investigator (RMIT)

SEMICONDUCTOR ROADMAP

The inclusion of technologies pursued at FLEET in the 2020 and 2021 editions of the IEEE International Roadmap for Devices and Systems (IRDS) ensures ongoing worldwide visibility of this pathway, particularly within the international semiconductor industry.

The addition of topological-insulator electronic devices (new in 2020) was facilitated in 2020 by FLEET Associate Investigator Prof Francesca Iacopi and this pathway will be expanded in the next (2022) roadmap.

Excitonic devices and domain wall logic also feature in the IRDS.

More at FLEET.org.au/roadmap

The inclusion of FLEET's science in the IRDS will ensure that industrial R&D leaders in semiconductors are aware of our work, and will be able to consider FLEET's breakthroughs among the potential solutions for future low-energy electronics, hence fulfilling the Centre's mission.

PROF MICHAEL FUHRER
FLEET Director

FLEET WILL:

- Translate FLEET science to industry
- Ensure the FLEET research mission continues beyond CE17 funding cycle (see FLEET's Sustainability Plan in the Centres strategic plan)
- Ensure Australia's next generation of science leaders are prepared for a wide range of future careers, including industry
- Establish strong, lasting links between Australian and international science communities

PREPARING OUR PEOPLE FOR CAREERS IN INDUSTRY

FLEET recognises that most STEM PhD graduates will end up in careers outside academia. Students need a diverse skills base to enhance their future job opportunities, ensuring readiness for whichever career path they pursue.

FLEET members have access to a tailored education and training program that emphasises not only technical skills but transferable skills in all stages of members' career development. This program builds future leaders in science and technology from academia to industry, in Australia and internationally (also see Training).

A focus on industry-relevant training in 2021 saw the introduction of an industry-engagement seminar series, with talks covering research commercialisation, commercialising semiconductor science, and transitioning from academia to commercialisation (see Industry engagement seminars).

Nine members were enrolled in a four-week course to develop research-impact and industry-engagement skills within Cruxes Innovation Base program.

In addition, training offered transferable skills applicable in any future career, including leadership and communication:

- Building Leadership skills (Women and Leadership Australia)
- Taking charge of your career, run by Dr Charlotte Hurry (former FLEET EO)
- Media and presentations training for members, in collaboration with ARC Centres for Mathematical and Statistical Frontiers (ACEMS) and Fragment-Based Design (CFBD)
- Effective personal and communication skills, run by Odyssey Training
- Idea Factory (see case study).

FLEET's new Translation Program Manager will work closely with Centre governance and working groups (Industry Relations and Education and Training committees, and the Centre's Student/ECR Working Group) to identify priority training programs relevant to research translation and commercialisation for 2022.

Semiconductor industry news is shared each month in FLEET's regular newsletter to familiarise members with this sphere, including local and international inventions, trends and events.

As part of FLEET's _, the Centre has brought in external industry-based mentors, in areas ranging from research, business to entrepreneurship.

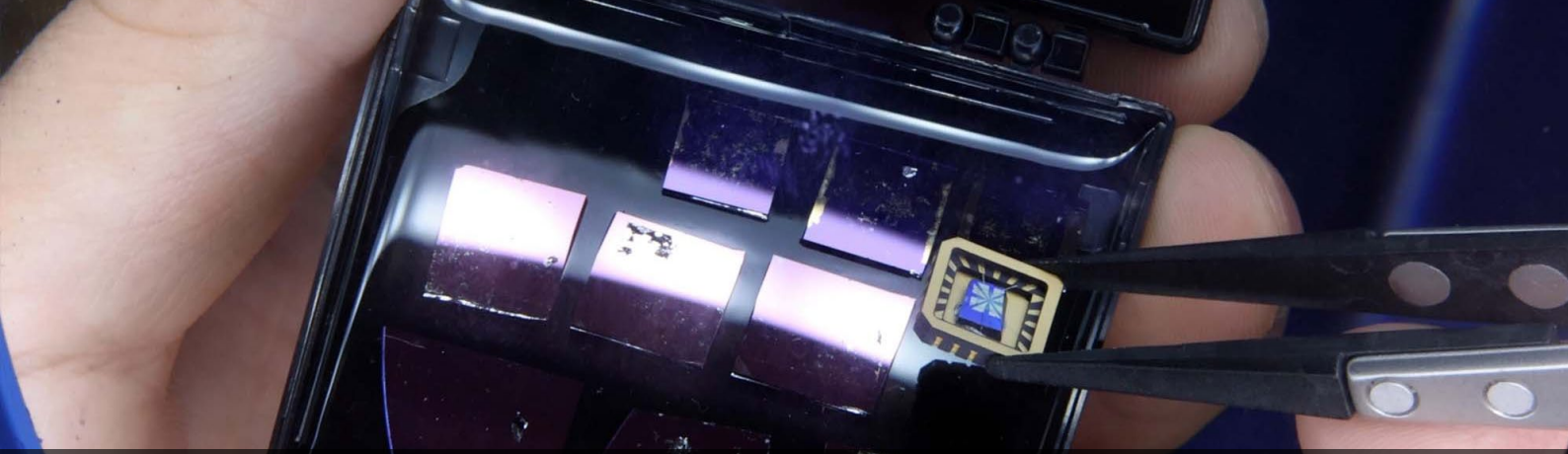
TRANSLATION STRATEGY DRIVEN BY MEMBERS: FLEET INDUSTRY RELATIONS COMMITTEE

With membership from each participating Centre node, and from Chief Investigator to PhD student, the FLEET Industry Relations Committee:

- Helps members understand the commercial value of their products and identify the commercial opportunities of their developments
- Works with the Education and Training Committee to offer industry-focused training to FLEET members
- Promotes engagement with end-users and commercial entities
- Trains and nurtures PhD students and early-career researchers so that they are industry ready, with committee members submitting suggestions for future member training.

FLEET Research Fellow Dr Semonti Bhattacharyya ran an eight-member Monash panel investigating the transition from academia to industry. The Monash Science event aimed at ECRs explored panellists' varied career pathways and roles in industry.

An industry-engagement brainstorming meeting in Q1 2022 will bring together committee members, Centre communications, and the Translation Program to help guide future engagement strategies.



New FLEET Translation Program shepherding scientific discovery towards commercialisation

Translating FLEET research to industry innovations with societal impact

CASE STUDY

A new FLEET program provides resources, advice and industry connections to develop Centre research into prototypes and technical demonstrations, helping translate FLEET research outcomes to industry innovations with wide societal impact, and developing key translation skills in Centre membership.

FLEET has engaged Dr Michael Harvey to guide FLEET members through the process of identifying promising projects for translation to industry, and shepherd them through the process of establishing linkages.

The FLEET Translation Program will:

- Identify Centre members with the desire and capability to translate their research
- Discover projects within FLEET that are ready for translation
- Train FLEET membership in key translation skills.

Strategic funds of $500k (2022–23) have been allocated to boost translation projects and provide targeted training, with three funding programs of between 6 and 18 months:

1. Higher degree by research (HDR) translation stipend allowing the recipient to participate in a research-translation project
2. Translation Fellowship providing paid time for a research fellow to undertake translation of their own research or to be part of an identified project, taking on leadership responsibilities
3. Facilitation project funding equipment, consumables, external vendor costs, etc. required to undertake a research-translation project, overcoming commercialisation barriers, gaining access to funding, or enabling larger projects with external partners.

The program was launched internally during the Centre's end-of-year meeting, in which Michael began discussions with several members already interested in translating their projects.

Priorities for 2022 include:

- Meeting FLEET people to learn about our research and opportunities
- Surveying membership to identify members and projects ready for translation and understand training needs
- Engaging new industrial partners
- Creating a rolling call for proposals for translation projects
- Establishing new training programs in areas of need, particularly in intellectual property
- Helping with advice about translation, commercialisation, industry, startups, and fundraising.

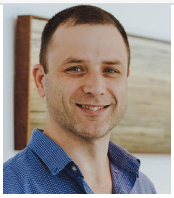
The new program focuses on members, and success will be seen in FLEET members forging new links with industry, FLEET knowledge and research translated into applications with industry partners, and FLEET members trained in translation skills.

Dr Michael Harvey developed the program as a flagship initiative within the ARC Centre of Excellence for Engineered Quantum Systems (EQUS), and the expansion to FLEET represents a move from 'local' success to even more impact in the Australian research community.

I'm always excited to hear about research and happy to answer any questions FLEET people have about translation, commercialisation, or my experiences in startups and industry.

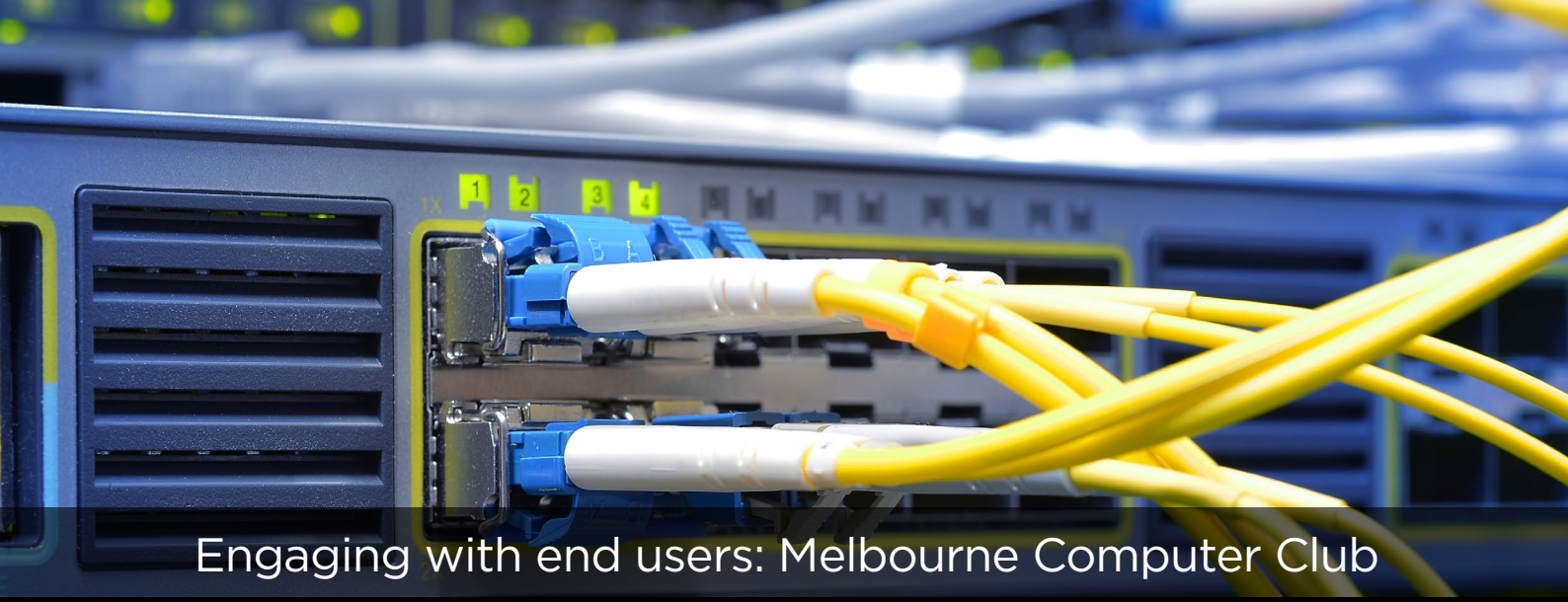
DR MICHAEL HARVEY
FLEET Translation Program Manager

Read more
FLEET.org.au



FLEET is constantly seeking to deliver the best opportunities to our people by looking at what works elsewhere.

PROF MATT DAVIS
FLEET Translation Program Director



Engaging with end users: Melbourne Computer Club

Fireside chat on the future of computing

CASE STUDY

Engaging with the Melbourne computing and electronics community in a 'fireside chat' forum in 2021, FLEET explained the intrinsic limitations of CMOS (silicon based) technology, and approaches investigated at FLEET.

What is the future of computing? As Moore's Law is approaching an end, new technologies are required to enable further advances in computational speed and energy-efficient data processing. As transistors took their first baby steps over half a century ago, the next generation of electronic switches is being born today.

Engaging with the Melbourne computing and electronics community in a fireside chat forum, FLEET's Dr Torben Daeneke (RMIT University) and Dr Iolanda Di Bernardo (Monash University) explained to the audience what the intrinsic limitations of the current CMOS-based technology are, and what some of the approaches are that FLEET members are looking into to address these issues.

Torben spoke about how new synthesis methods can deliver materials that may be key to finding solutions.

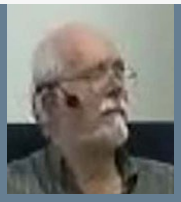
Iolanda spoke about atomically-thin materials, how she fabricates them in the ultra-high vacuum synthesis chambers at Monash, and the concept of topological edge states.

The around 20 audience members were extremely interested in FLEET's work, and spent about 90 minutes discussing chemistry, physics and electronics in a moderated panel discussion. Particular areas of interest included the synthesis methods of the materials, their versatility beyond low-energy electronics applications, and the wider topic of research in Australia.

With a heritage dating back to 1984, the Melbourne PC User Group is Australia's largest computer club with 1400 members, hosting regular talks and electronics workshops.

Iolanda and Torben were guests at a meeting of the Microcontroller special interest group, whose members are specifically interested in electronics and related topics.

The club initiated the contact after reading about Torben's recent transparent electronics work in a story published on the electronics media platform Tech Briefs.



There was a lot of interest and questions from the other members, so it was a pretty lively and stimulating conversation. We all enjoyed hearing about the research being done on a broad front to develop novel methods of making active electronics devices.

DAVID STONIER-GIBSON
President Melbourne Computer Club

Read more
FLEET.org.au

INNOVATE

FLEET RESEARCH CAPABILITIES AND OUTCOMES

FLEET themes

FLEET's approach is multidisciplinary, combining efforts across condensed-matter, cold-atom physics, material science and nanofabrication.

FLEET is pursuing the following research themes to develop systems in which electrical current can flow with near-zero resistance:

RESEARCH THEME 1: TOPOLOGICAL MATERIALS

FLEET's first research theme seeks electrical current flow with near-zero resistance based on a paradigm shift in materials science that yielded 'topological insulators'.

Topological insulators conduct electricity only along their edges, and strictly in one direction, without the 'backscattering' that dissipates energy in conventional electronics.

Read more

RESEARCH THEME 2: EXCITON SUPERFLUIDS

FLEET's second research theme uses a quantum state known as a superfluid to achieve electrical current flow with minimal wasted dissipation of energy.

In a superfluid, scattering is prohibited by quantum statistics, so charge carriers can flow without resistance.

Superfluids may be formed by excitons (electrons bound to 'holes').

Read more

RESEARCH THEME 3: LIGHT TRANSFORMED MATERIALS

FLEET's third research theme represents a paradigm shift in material engineering, in which materials are temporarily forced out of equilibrium.

For example, zeroresistance paths for electrical current can be created using short, intense bursts of light, temporarily forcing matter to adopt a new, distinct topological state.

Read more

These research approaches are enabled by the following technologies:

ENABLING TECHNOLOGY A: ATOMICALLY THIN MATERIALS

Each of FLEET's three research themes is heavily enabled by the science of novel, atomically-thin, two-dimensional (2D) materials.

These materials can be as thin as just one single layer of atoms, with resulting unusual and useful electronic properties.

To provide these materials FLEET draws on extensive expertise in materials synthesis in Australia and internationally.

Read more

ENABLING TECHNOLOGY B: NANO DEVICE FABRICATION

FLEET's research sits at the very boundary of what is possible in condensed-matter physics. At the nano scale, nanofabrication of functioning devices will be key to the Centre's success.

Nano-device fabrication and characterisation links many of FLEET's groups and nodes with diverse fields of expertise such as device fabrication or measurement.

Read more

FLEET WILL:

- Develop and progress new concepts for low-energy electronics
- Increase the global science community's fundamental understanding of quantum materials and electronic devices
- Build Australian research capacity for quantum materials, semiconductors and electronic devices
- Enable discoveries at the scientific frontier

FLEET team

CHIEF INVESTIGATORS

PROF MICHAEL FUHRER, MONASH

Director – FLEET

Michael synthesises and studies new, ultra-thin topological Dirac semimetals and two-dimensional (2D) topological insulators with large bandgaps within Research theme 1, as well as working in themes 2 and 3 and Technology A.

A pioneer of the study of electronic properties of 2D materials, Michael is a Fellow of the American Physics Society, and Fellow of the American Association for the Advancement of Science.

ALEX HAMILTON, UNSW

DEPUTY DIRECTOR & LEADER OF RESEARCH THEME 1 – TOPOLOGICAL DISSIPATIONLESS SYSTEMS

Alex leads Research theme 1 and develops new techniques to fabricate and study both natural and artificially engineered topological materials.

An internationally recognised expert on the properties of electrons and holes in semiconductor nanostructures, Alex is a UNSW Scientia Professor and a Fellow of the American Physical Society.

AGUSTIN SCHIFFRIN, MONASH

Agustin investigates optically-driven topological phases using ultra-fast photonics, pump-probe spectroscopy and time-resolved scanning probe microscopy within Research themes 1 and 3.

CHRIS VALE, SWINBURNE

Chris synthesises and characterises topological phenomena in 2D, ultracold fermionic atomic gases, investigating new forms of topological matter within Research theme 3.

DIMI CULCER, UNSW

Dimi studies theoretical charge and spin transport in topological materials and artificial graphene with strong spin-orbit coupling within Research theme 1.

ELENA OSTROVSKAYA, ANU

LEADER OF RESEARCH THEME 2 – EXCITONIC DISSIPATIONLESS SYSTEMS

Leading Research theme 2, Elena directs theoretical and experimental research on exciton and exciton-polariton Bose-Einstein condensation and superfluidity near room temperature.

JAN SEIDEL, UNSW

Jan uses scanning probe microscopy (SPM) to study complex oxide materials systems for Research theme 1, and nanoscale SPM patterning in topological materials in Enabling technology B.

JARED COLE, RMIT

CHAIR OF SPECIAL GOVERNANCE COMMITTEE – EDUCATION AND TRAINING

Jared applies quantum theory to study electronic transport in nanostructures and the behaviour of topologically-protected conduction channels in electronic devices.

JEFF DAVIS, SWINBURNE

CHAIR OF SPECIAL GOVERNANCE COMMITTEE – EQUITY AND DIVERSITY

Jeff uses femtosecond laser pulses in Swinburne's ultra-fast science facility to modify electronic band structure and realise Floquet topological insulators in 2D materials within Research theme 3.

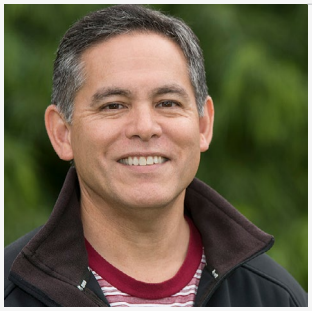
JULIE KAREL, MONASH

CHAIR OF SPECIAL GOVERNANCE COMMITTEE – OUTREACH

Julie's research at the intersection of materials science and condensed-matter physics applies structural disorder to modify the magnetic and electronic properties of materials, seeking new materials for emerging low-energy nanoelectronic and magnetoelectronic devices.

KOUROSH KALANTAR-ZADEH, UNSW

Kourosh develops novel 2D semiconducting materials and fabrication techniques for advanced devices, using electron and ion-beam lithography in Research themes 1 and 3 and Enabling technology B.



KRIS HELMERSON, MONASH

LEADER OF RESEARCH THEME 3 – DYNAMICALLY CONTROLLED DISSIPATIONLESS SYSTEMS

Heading Research theme 3, Kris uses ultra-cold atoms in an optical lattice to investigate driven Floquet systems, and topological states in multidimensional extensions of the kicked quantum rotor. Kris is a Fellow of the American Physical Society.

LAN WANG, RMIT

LEADER OF ENABLING TECHNOLOGIES B – DEVICE FABRICATION

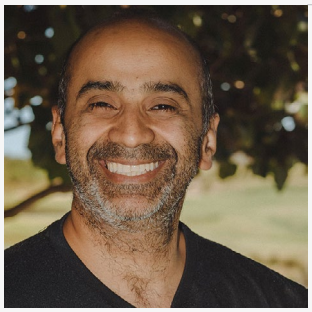
Leading Enabling technology B, Lan also directs study of high-temperature quantum anomalous Hall systems in Research theme 1 and synthesis of novel 2D materials for Enabling technology A.

MATTHEW DAVIS, UQ

Within Research theme 3, Matt studies transitions between novel nonequilibrium states of matter, focusing on relaxation in non-equilibrium and destructive effects of coupling to the environment. Matt is a Fellow of the American Physical Society.

MEERA PARISH, MONASH

Meera develops many-body theories spanning electron-hole systems and ultracold atomic gases. In Research theme 2, she investigates exciton-polariton condensates, while in Research theme 3, she studies non-equilibrium quantum systems such as coupled kicked rotors.



NAGARAJAN 'NAGY' VALANOOR, UNSW

Nagy explores oxides for low-energy electronic devices founded on topological materials in Enabling technology A and synthesises ferroelectric and ferromagnetic materials within Research theme 1.

NIKHIL MEDHEKAR, MONASH

Nikhil investigates the electronic structure of atomically-thin topological insulators and interfaces in Research theme 1 via quantum mechanical simulations on massively-parallel, high-performance computing systems.

OLEG SUSHKOV, UNSW

Oleg leads two theoretical investigations within Research theme 1: artificial nanofabricated materials and laterally-modulated oxide interfaces.

OLEH KLOCHAN, UNSW

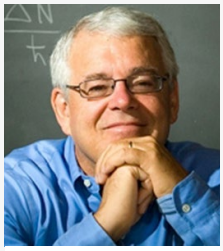
Oleh leads the fabrication and measurements of artificially-designed topological insulators using conventional semiconductors in Research theme 1.

XIAOLIN WANG, UOW

LEADER OF ENABLING TECHNOLOGIES THEME A
– ATOMICALLY-THIN MATERIALS

Directing Enabling technology A, Xiaolin investigates charge and spin effects in magnetic topological insulators, and leads synthesis of FLEET's single-crystal bulk and thin-film samples.

PARTNER INVESTIGATORS



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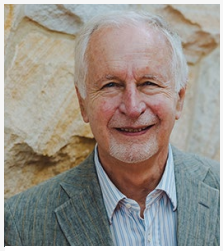
Andrea Perali
University of Camerino

Anton Tadich
Australian Synchrotron

Antonio Castro Neto
National University of Singapore

Barbaros Oezyilmaz
National University of Singapore



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California Institute of Technology

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Wroclaw University of Science and Technology

Hai-Qing Lin
Beijing Computational Science Research Center

Ian Spielman
University of Maryland

Johnpierre Paglione
University of Maryland

Justin Hodgkiss
MacDiarmid Insitute

Kirrily Rule
ANSTO

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High Magnetic Field Lab, Chinese Academy of Science

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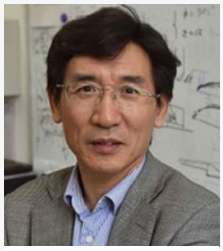
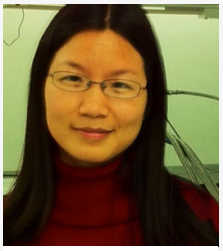


Qi-Kun Xue
Tsinghua University

Shaffique Adam National
University of Singapore



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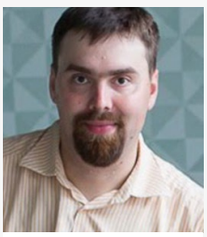

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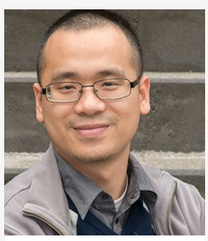

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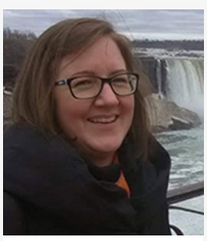

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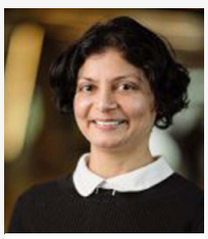

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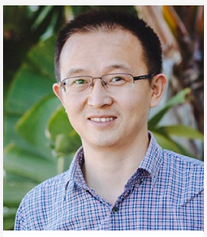

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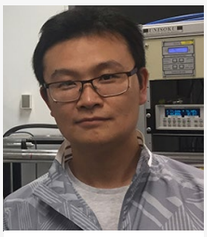

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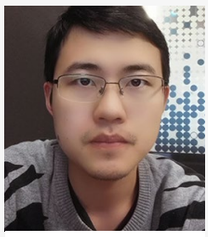

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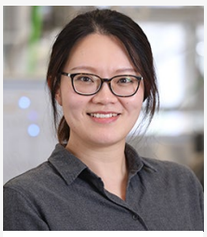

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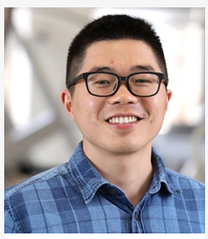

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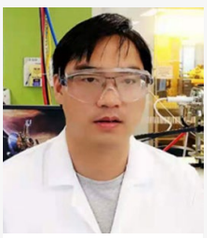

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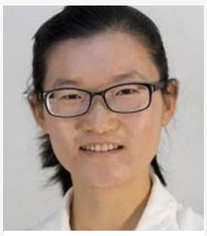

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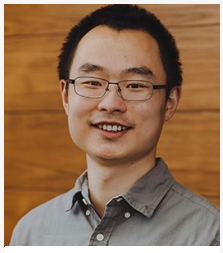

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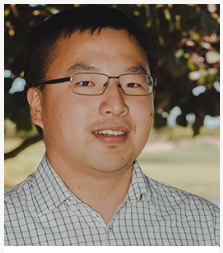

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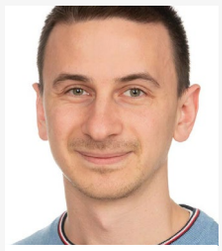

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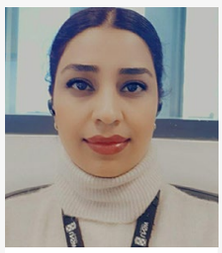

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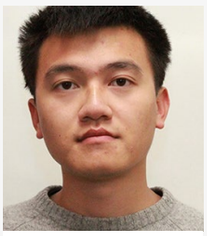

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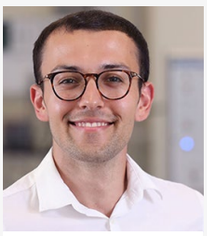

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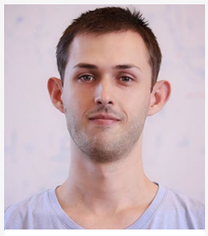

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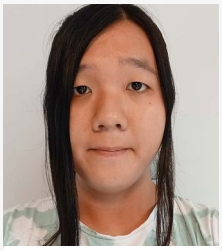

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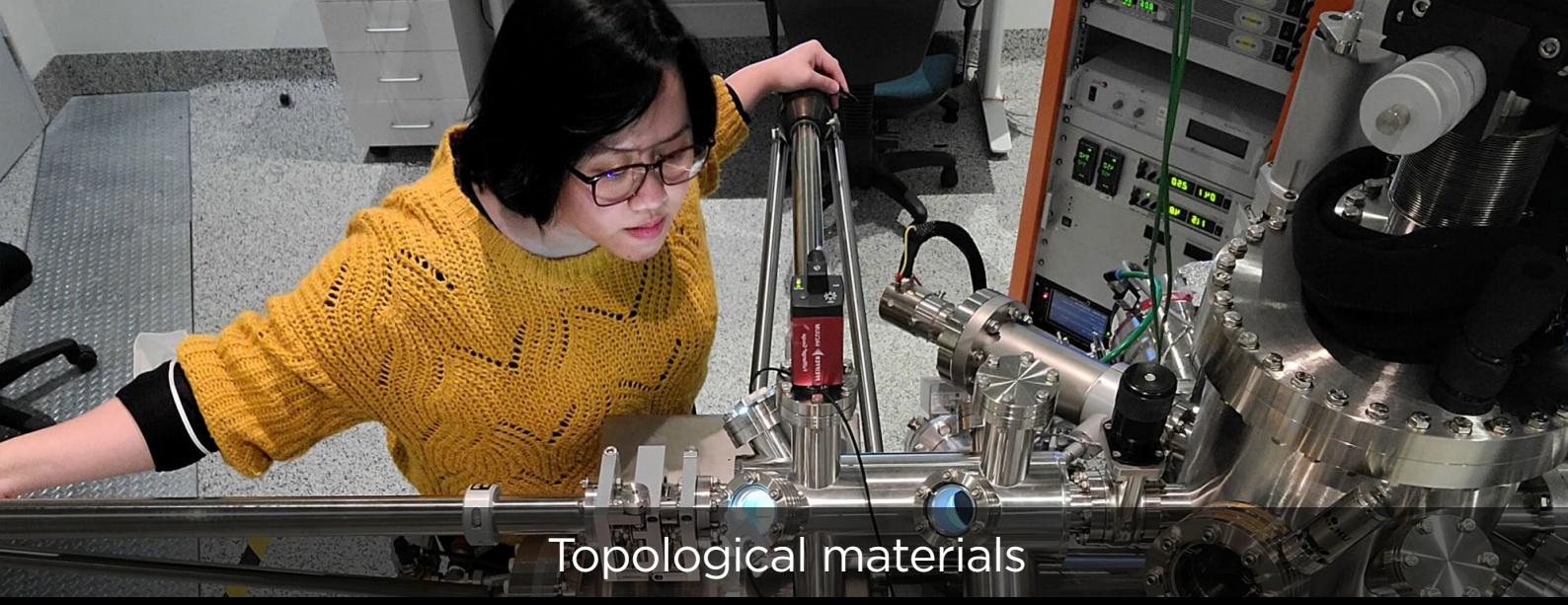


Topological materials

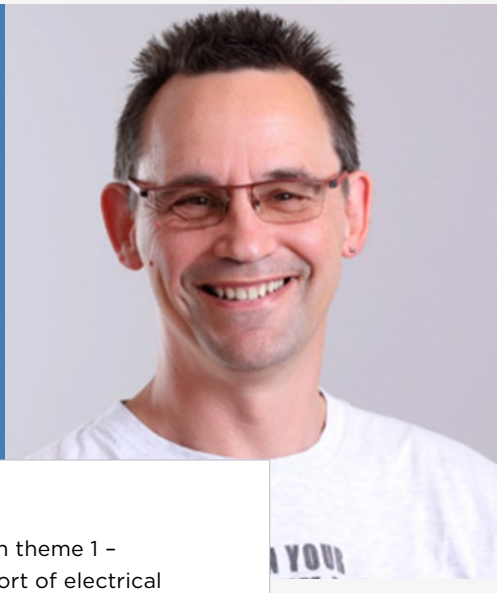
Research theme 1

PROF ALEX HAMILTON

Leader, Research theme 1
UNSW

Expertise: Semiconductor nanoelectronics and nanofabrication, 2D materials, electronic conduction in nanoscale devices, spin-orbit interactions, behaviour of holes in semiconductor nanostructures

Research outputs (Alex Hamilton):
230+ papers
4700+ citations
h-index 35 (Scopus)

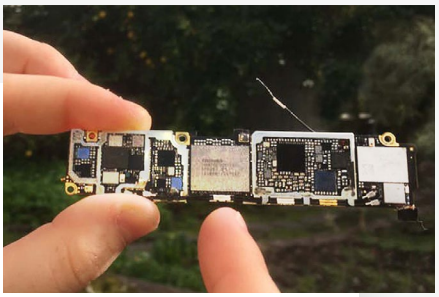


> The ambitious goal of Research theme 1 – realising dissipationless transport of electrical current at room temperature and developing novel devices capable of controlling this current – connects scientists from Australia and abroad.

CASE STUDY

Beating Boltzmann's tyranny: Surpassing lower limit on computing energy consumption

Read our case study



FLEET's topological materials research theme seeks to achieve electrical current flow with near-zero resistance, based on a paradigm shift in the understanding of condensed-matter physics and materials science: the advent of topological insulators.

Unlike conventional insulators, which do not conduct electricity at all, topological insulators conduct electricity, but only along their edges.

Along those topological edge paths, electrons can only move in one direction, without the 'backscattering' that dissipates energy in conventional electronics.

FLEET's challenge is to create topological materials that will operate as insulators in their interior and have switchable conduction paths along their edges.

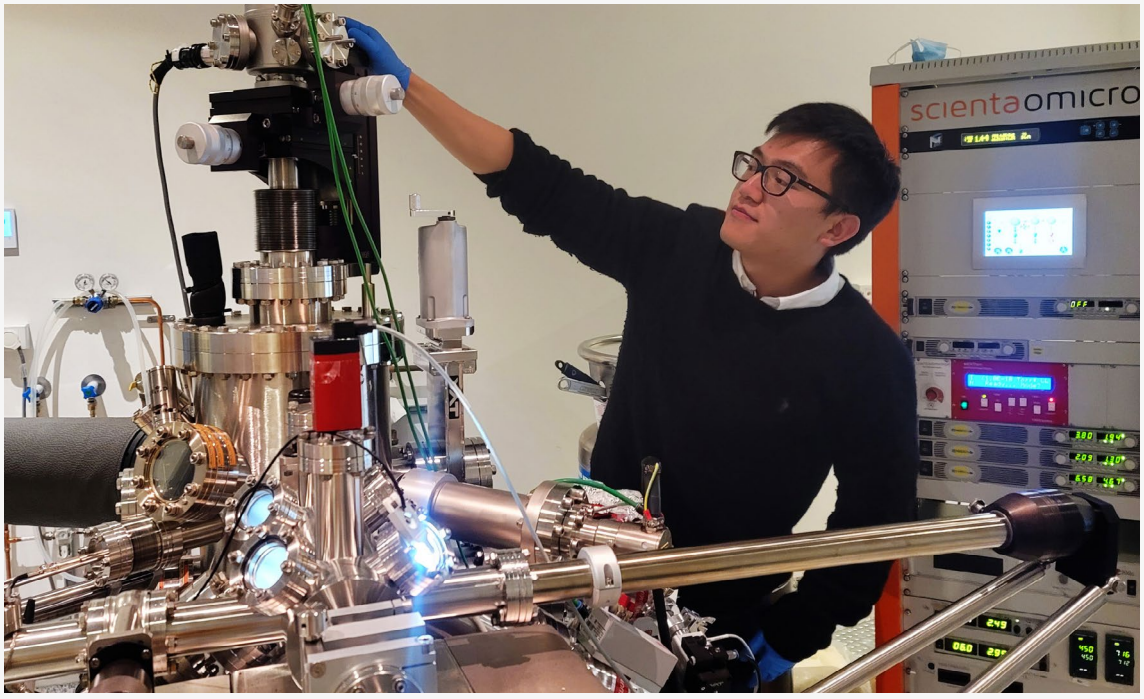
Topological transistors will 'switch', just as a traditional (silicon-based) CMOS transistor does, with a 'controlling' voltage switching the edge paths between being a topological insulator ('on') and a conventional insulator ('off').

For the new technology to become a viable alternative to traditional transistors, the desired properties must be achievable at room temperature (otherwise, more energy is lost in maintaining ultra-low temperatures than is saved by the low-energy switching).

Approaches used are:

- Magnetic topological insulators and quantum anomalous Hall effect (QAHE)
- Topological Dirac semimetals
- Artificial topological systems.

FLEET has placed topological insulator electronics devices in the IEEE International Roadmap for Devices and Systems.



2021 HIGHLIGHTS

- Overcoming Boltzmann's tyranny, surpassing the lower limit on computing energy consumption (see **case study**)
- Establishing potential of negative capacitance to lower switching energy by a factor of ten in future topological quantum transistor (TQFET, patented)
- Developing a new approach to making low-noise, low-disorder quantum devices by growing crystalline metal gates as part of the semiconductor crystal, creating atomically perfect interfaces (patented)
- Detecting the spin-gap zero mode in 1D quantum nanowires as a critical step towards reproducible Majorana zero modes
- Reviews:
  - Epitaxial Na_3Bi films, a 3D analogue of graphene
  - Heterostructures of topological insulators and ferromagnetics

IN 2022 FLEET WILL...

- Start testing devices with potential to realise an artificial topological insulator in gallium arsenide
- Improve the control of artificial lattices to create more robust artificial bandstructure
- Develop a detailed understanding of electronic transport in high quality bilayer graphene
- Study effects of interactions and supermodulation in monolayer and bilayer graphene
- Continue developing new models for thin Dirac semimetals and amorphous topological insulators
- Study transverse magnetic focussing in 2D systems
- Continue study of topological and Josephson effects in edge state conduction
- Establish new framework from materials to device modelling in 2D vdW materials
- Establish theory for electronic correlations in 2D metal-organic frameworks on any general substrate
- Calculate spin Hall conductivity in magnetic, topological materials from first principles methods
- Further develop understanding of non-linear response, develop quantum theory of optical currents, and understand quadrupolar photovoltaic effect

DEFINITIONS

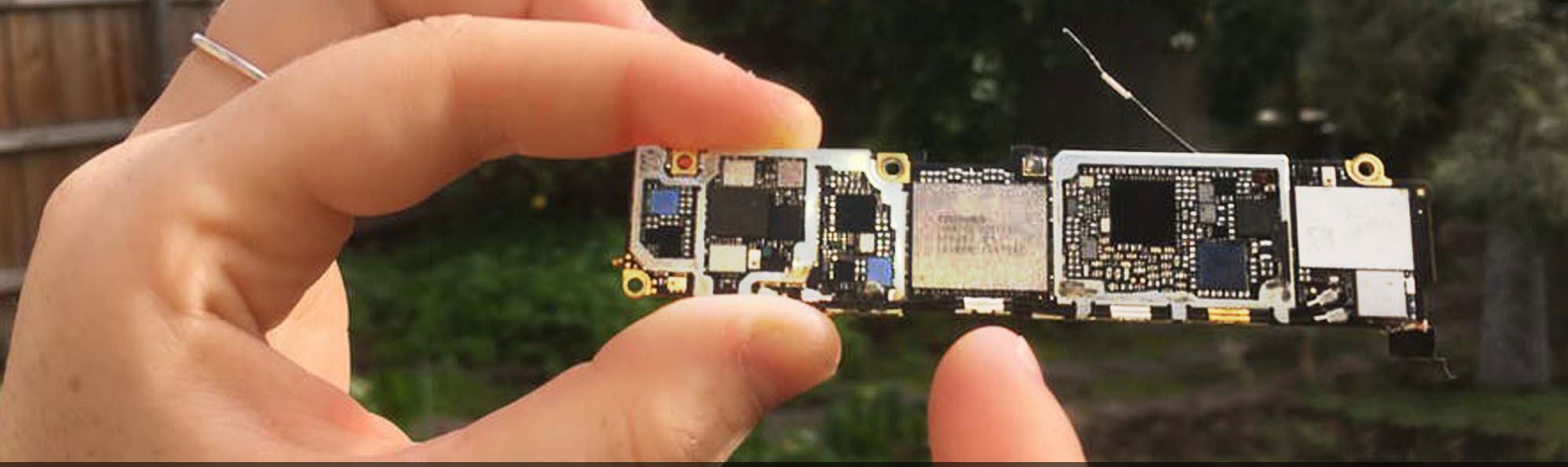
Artificial topological systems Artificial analogues of graphene and 2D topological insulators

Heterostructures A structure made by stacking layers of different semi-conducting materials

Bandstructure The allowed energies for electrons in a material oocur in 'bands' separated by 'bandgaps' which are energy gaps that define whether a material is a conductor, insulator or semiconductor; a large bandgap is required for a material to still be topological at room temperature

DID YOU KNOW?

The semiconductor industry decadal plan identifies a future mis-match between the growth of computing and available global energy capacity.



Beating Boltzmann's tyranny: Surpassing lower limit on computing energy consumption

Topological insulators can reduce transistor switching energy by a factor of four, defeating 'Boltzman's tyranny', which puts a lower limit on operating voltage

CASE STUDY

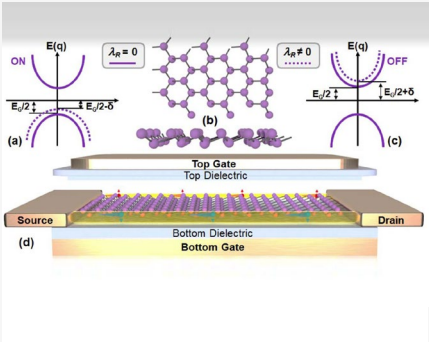
A landmark theoretical FLEET study in 2021 confirms the potential for topological materials to substantially reduce the energy consumed by computing, defeating Boltzmann's tyranny, a lower limit on operating energy.

The collaboration of researchers from three FLEET nodes showed that transistors based on topological insulators rather than conventional semiconductors could reduce the gate voltage by half, and the energy used by each transistor by a factor of four.

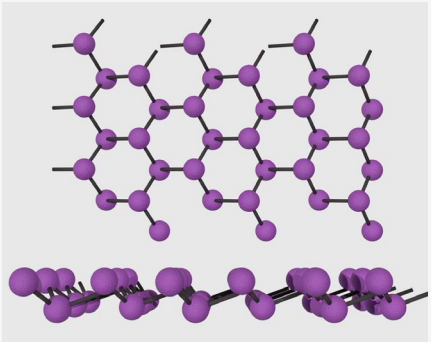
This overcomes the famous Boltzmann's tyranny, which puts a lower limit on transistor switching energy.

The research discovered something surprising: a gate voltage applied to a topological insulator could create a barrier to electron flow that is larger than the voltage itself times the electron charge, a result previously thought impossible.

Transistors switch on and off based on application of a gate voltage, with the energy used to charge up the gate electrode lost each time each transistor switches. With literally billions of transistors turning on and off billions of times each second, this adds up to a lot of energy.



The theoretical study confirms a topological transistor would defeat Boltmann's tyranny, a lower limit on operating energy.



Bismuthene (a single atom-thick layer of bismuth atoms) is a candidate material for a topological transistor

In conventional semiconductor transistors, a gate voltage shifts the semiconductor's 'bandgap' (or the range of energies within which electrons are forbidden) to allow (the 'on' state) or block (the 'off' state) incoming electrons.

In an ideal transistor, 1 volt applied to the gate would move up the range of energies blocked by 1 electron-volt. But leakage 'tyranny' puts a lower limit on that switching energy.

With electrons' energies inherently 'smeared out', there are always a few electrons with sufficiently-high energy to make it over the barrier. This 'leakage' current represents wasted energy.

To avoid wasted leakage current requires a minimum gate voltage that puts a lower limit on switching energy.

Named 'Boltzmann's tyranny', after the scientist who first described the 'smearing' of the energies of particles by temperature, this limits how small the operating gate voltage can be for a transistor, no matter what material it is made of.

However, FLEET researchers wondered whether Boltzmann's tyranny could be overcome in a new type of transistor using topological insulators, switched via an electric field rather than gate voltage.

Two-dimensional topological insulators can function as the 'on' state of a new type of transistor, with current carried by the conducting edges.

The conducting state of a such a material can be changed by an electric field, switching the material from dissipationless conduction (a topological insulator with a negative bandgap) to non-conduction (effectively, functioning as a regular semiconductor, with a positive bandgap blocking electron flow).

Crucially, the team found that, unlike a regular semiconductor, the increase in the bandgap in the topological insulator could be larger than the voltage applied to the gate, beating Boltzmann's tyranny.

The next steps will be to confirm these findings in the laboratory, using candidate materials such as bismuthene, with FLEET working to synthesise these new materials, characterise them, and incorporate them into electronic devices.

This research relates to FLEET milestones 1.4 and 1.8.
See page 13 of the strategic plan.

This study was published in *Nano Letters* in March 2021 (See publications).

With the right materials, a topological transistor could 'switch' at voltages half that of conventional silicon-based transistors, requiring only one fourth the energy.

A/PROF DIMI CULCER (UNSW)
Co-Author FLEET Chief Investigator

More at FLEET.org.au/boltzmann

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Exciton superfluids

Research theme 2

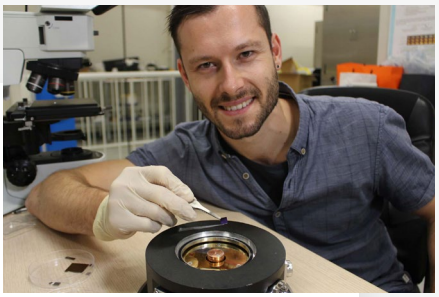
PROF ELENA OSTROVSKAYA

Leader, Research theme 2
ANU

Expertise: non-linear physics, quantum degenerate gases, Bose-Einstein condensates, exciton-polaritons

Research outputs (Elena Ostrovskaya):
140+ papers
4900+ citations
h-index 37 (Scopus)

> Research theme 2 highlights FLEET's collaborative nature, involving cross-disciplinary input between nodes and with several Partner Investigators.



CASE STUDY

Sandwich-style construction: towards ultra-low-energy exciton electronics

Read our case study

FLEET's second research theme uses a quantum state known as a superfluid to achieve electrical current flow with minimal wasted dissipation of energy.

In a superfluid, scattering is prohibited by quantum statistics, so electrical current can flow without resistance.

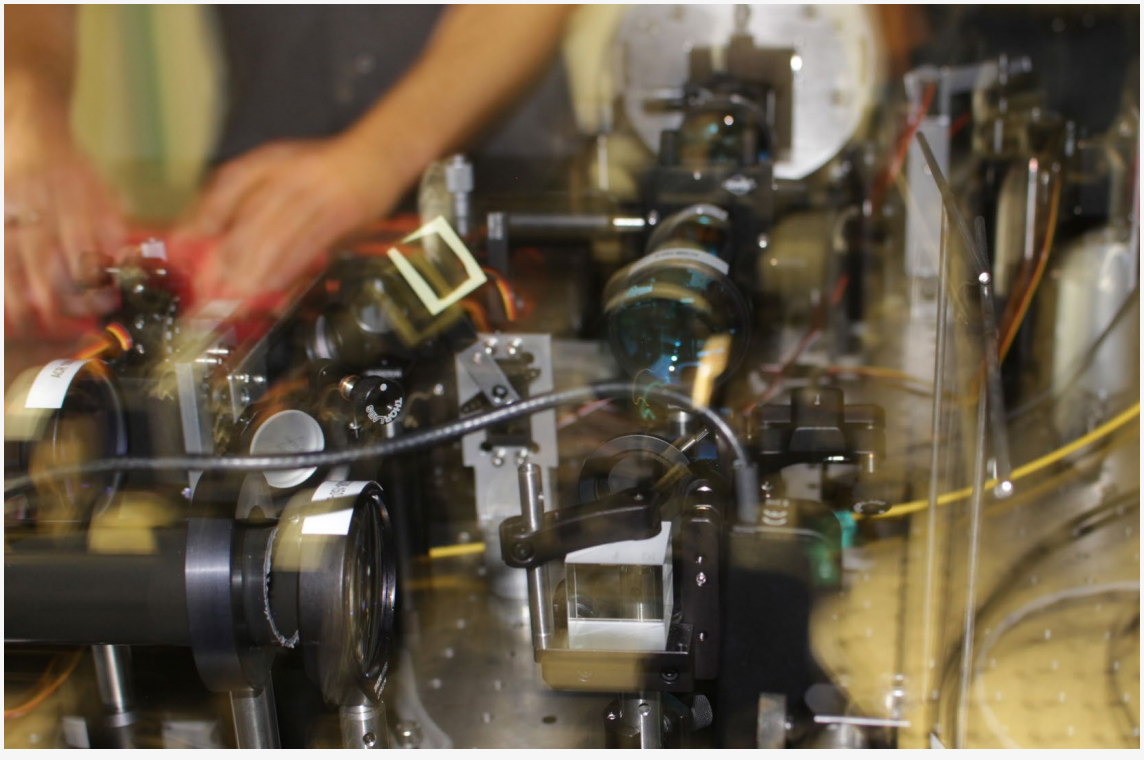
A superfluid is a quantum state in which all particles flow with the same momentum, and no energy is lost to other motion. Particles and quasi-particles, including both excitons and exciton-polaritons, can form a superfluid.

Researchers are seeking to create superfluid flows using three approaches:

- Exciton-polariton bosonic condensation in atomically-thin materials
- Topologically-protected exciton-polariton flow
- Exciton superfluids in twin-layer materials.

If exciton-superfluid devices are to be a viable, low-energy alternative to conventional electronic devices, they must be able to operate at room temperature, without energy-intensive cooling. Thus, FLEET seeks to achieve superfluid flow at room temperature, using atomically-thin semiconductors as the medium for the superfluid.

FLEET is a leading contender in an international race to be the first to achieve superfluid condensate of exciton-polaritons



2021 HIGHLIGHTS

- Observing room-temperature dissipationless transport of exciton-polaritons in monolayer WS_2 (see **case study**)
- Observing optically-induced topological phase transition of novel non-Hermitian topological invariant in exciton-polariton systems
- Probing biexcitons and exciton-polarons in ultra-fast pump-probe spectroscopy measurements
- Observing collective oscillations and measurement of the speed of sound in exciton-polariton superfluid
- Developing theories of polariton-polariton and polariton-electron interactions, and theory of quantum correlations for confined polaritons
- Developing a comprehensive theory of vortex dynamics and pinning in superfluid flows.

IN 2022 FLEET WILL...

- Continue to explore transition to exciton-polariton condensation in atomically-thin TMDCs
- Explore the topologically nontrivial exciton-polariton systems
- Continue to explore, both experimentally and theoretically, the consequence of interactions in exciton-polariton systems
- Continue investigation of properties of excitons and exciton-polaritons in ultra-fast spectroscopy experiments
- Develop a theory for nonequilibrium superfluid flow
- Develop a nonequilibrium theory for the polariton condensate.

DEFINITIONS

Exciton-polariton Part matter and part light quasi-particle: an exciton bound to a photon

TMDCs Transitional metal dichalcogenide crystals (TMDCs) are excellent hosts for excitons, hosting excitons that are stable at room temperature and interact strongly with light

DID YOU KNOW?

FLEET is the first group to have observed dissipationless transport of exciton-polaritons at room temperature.

Sandwich-style construction: towards ultra-low-energy exciton electronics

New microcavity construction technique allows observation of robust, room-temperature exciton transport

CASE STUDY

A new FLEET-led 'sandwich-style' fabrication process placing an atomically-thin semiconductor between two mirrors allows a significant step towards ultra-low-energy electronics based on exciton-polariton.

The breakthrough, led by PhD candidate Matthias Wurdack at ANU, demonstrated robust, dissipationless propagation of an exciton mixed with light bouncing between the high-quality mirrors.

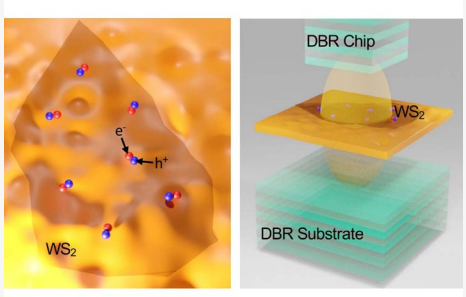
Conventional electronics relies on flowing electrons, or holes (a hole is the absence of an electron, i.e. a positively-charged quasi-particle).

Instead, FLEET's ANU team investigated an alternative future electronic technology using excitons because, in principle, they could flow in a semiconductor without losing energy by forming a collective superfluid state. Also, excitons in novel, actively-studied atomically-thin semiconductors are stable at room temperature.

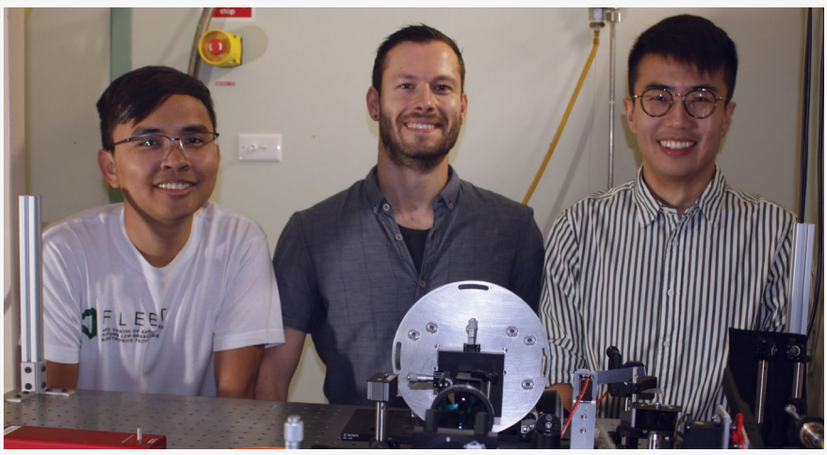
Despite this promise for low-energy electronics and sensors, the properties of atomically-thin semiconductors, including the flow of excitons, are strongly affected by disorder or imperfections, which can be introduced during fabrication.

The ANU-led FLEET team – with Centre colleagues at Swinburne University of Technology and FLEET Partner institution Wroclaw University – coupled the excitons in an atomically-thin material to light, to demonstrate for the first time their long-range propagation without any dissipation of energy, at room temperature.

Trapping light between two parallel high-quality mirrors in an optical microcavity an exciton (matter) to bind with a photon (light), forming the



Electron-hole pairs in an atomically-thin material (substrate dielectric disorder similar size to excitons), and hybridisation of excitons and photons leading to formation of polaritons, reducing dielectric disorder.



FLEET ANU researchers: from left Research Fellow Dr Eliezer Estrecho, PhD student Matthias Wurdack, PhD student Tinghe Yun (Credit: Phil Dooley ANU)

hybrid particle an exciton-polariton. Microcavities are micrometre-scale structures with an optical medium sandwiched between ultra-reflective mirrors, used to confine light such that it forms exciton-polaritons.

In the 2021 study, a new 'sandwich-style' fabrication process for the optical microcavity allowed the researchers to minimise damage to the atomically-thin semiconductor and to maximise the interaction between the excitons and the photons. The exciton-polaritons formed in this structure were able to propagate without energy dissipation across tens of micrometres, the typical scale of an electronic microchip.

A high-quality optical microcavity ensuring the longevity of the light (photonic) component of exciton-polaritons was the key to these observations. "We found that exciton-polaritons can be made remarkably stable if microcavity construction avoids damage of the fragile semiconductor sandwiched between the mirrors during fabrication," says Matthias.

"The choice of the atomically-thin material in which the excitons travel is far less important than the construction."

"We fabricate the entire top structure separately, and then place it on top of the semiconductor mechanically, like making a sandwich. Thus we avoid any damage to the atomically-thin semiconductor, and preserve the properties of its excitons."

The researchers optimised this sandwiching method to make the cavity very short, maximising the exciton-photon interaction.

"This demonstration, for the first time, of dissipationless transport of room-temperature polaritons in atomically-thin TMDCs is a significant step towards future, ultra-low-energy exciton-based electronics," says group leader Prof Elena Ostrovskaya (ANU).

Furthermore, the researchers confirmed that exciton-polaritons can propagate in the atomically-thin semiconductor for tens of micrometres (easily far enough for functional electronics) without scattering on material defects. (In fact, the travel length of excitons in these materials is dramatically reduced by these defects.) The exciton-polaritons' high coherence bodes well for their potential as information carriers.

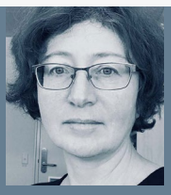
"This long-range, coherent transport was achieved at room temperature, which is important for development of practical applications of atomically-thin semiconductors," said Matthias.

If future excitonic devices are to be a viable, low-energy alternative to conventional electronic devices, they must be able to operate at room temperature, without the need for energy-intensive cooling.

This research relates to FLEET milestones M2.2.1 and M2.2.4.
See page 17 of the strategic plan.

The study was published in *Nature Communications* in September 2021 (See publications).

This demonstration is a significant step towards future, ultra-low-energy exciton-based electronics.



PROF ELENA OSTROVSKAYA (ANU)
Co-author FLEET Chief Investigator

More at FLEET.org.au/sandwich

COLLABORATING FLEET PERSONNEL

PhD student
Matthias Wurdack
Australian National University

Research Fellow
Eliezer Estrecho
Australian National University

PhD student
Tinghe Yun
Monash University

Research Fellow
Maciej Pieczarka
Australian National University (Alum)

Research Fellow
Stuart Earl
Swinburne University of Technology

Chief Investigator
Jeff Davis
Swinburne University of Technology

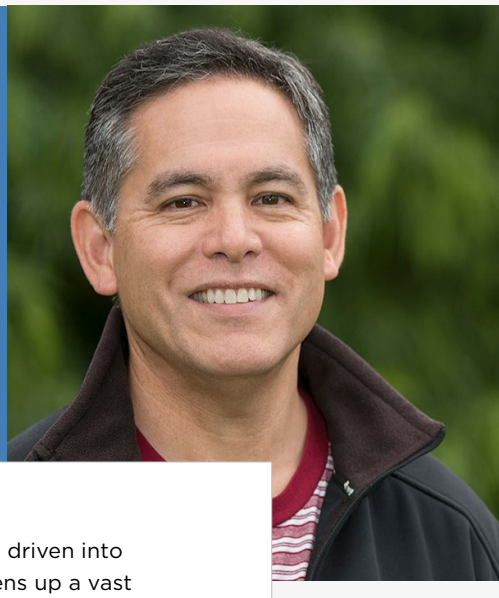
Chief Investigator
Elena Ostrovskaya
Australian National University

DID you KNOW

Two-dimensional materials have extraordinary properties such as extremely-low resistance or highly-efficient interactions with light. However, they are inherently fragile.

Light-transformed materials

Research theme 3



PROF KRIS HELMERSON

Leader, Research theme 3
Monash

Expertise: ultra-cold collisions of atoms, matter-wave optics, non-linear atoms dynamics, atomic gas superfluidity, atomtronics, non-linear atom optics

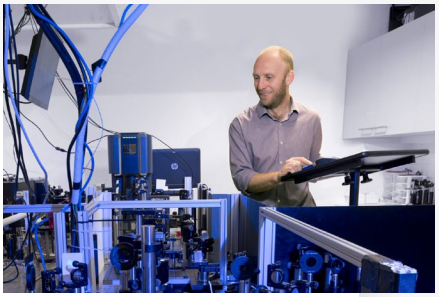
Research outputs (Kris Helmerson):
110+ papers
5100+ citations
h-index 33 (Scopus)

> The ability to control materials driven into non-equilibrium behaviour opens up a vast landscape for future electronics.

CASE STUDY

‘Target identified’: teaching a machine how to identify imperfections in 2D materials

Read our case study



FLEET's third research theme represents a paradigm shift in material engineering, in which materials are temporarily forced out of equilibrium.

The zero resistance paths for electrical current sought at FLEET can be created using two non-equilibrium mechanisms:

- Short (femtosecond), intense bursts of light temporarily forcing matter to adopt a new, distinct topological state.
- Dynamically-engineered dissipationless transport.

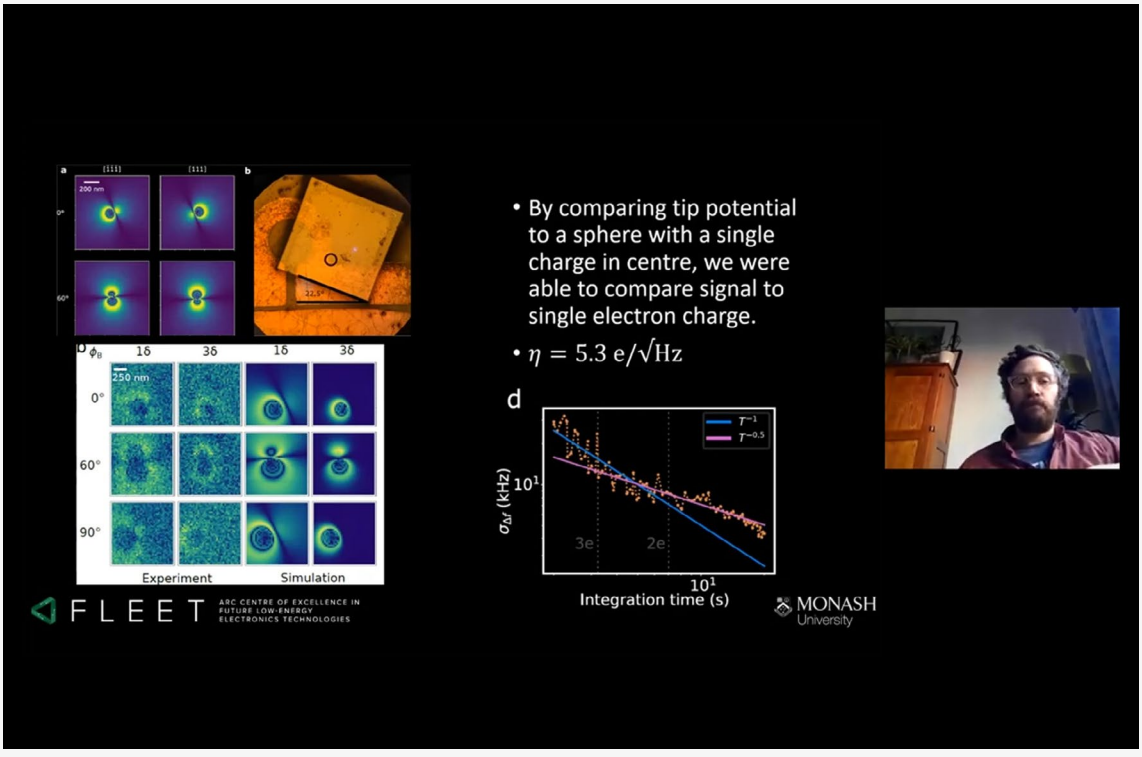
Very short, intense pulses of light are used to force materials to become topological insulators (see Research theme 1) or to shift into a superfluid state (see Research theme 2).

The forced state achieved is only temporary, but researchers learn an enormous amount about the fundamental physics of topological insulators and superfluids as they observe the material shifting between natural and forced states over a period of several microseconds.

By using ultra-short pulses to switch between the dissipationless-conducting and normal states, we can also create ultra-fast opto-electronic switching of this dissipationless current.

The second approach typically uses periodic perturbations (usually, optical) to modify the time-averaged behaviour of the system.

FLEET is the first and the only team to have made a hybrid condensate at cryogenic temperature



2021 HIGHLIGHTS

- Applying machine learning to automate characterisation of atomically-thin materials (see **case study**)
- Directly measuring biexcitons in monolayer WS_2
- Measuring the dynamics of quenched Fermi gas
- Developing theoretical understanding of the quantum behaviour of a heavy impurity in a Bose gas.

IN 2022 FLEET WILL...

- Identify topological phase transitions in a Floquet system using terahertz spectroscopy
- Demonstrate Floquet control of bandstructure in graphene
- Investigate quench dynamics in a 2D Fermi gas near a p-wave Feshbach resonance
- Develop theoretical understanding of (Floquet) kicked-rotor system with spin-orbit coupling
- Image currents in 2D material using quantum microscopy
- Develop new theoretical approaches to model interactions between quantum impurities and quasi-particles.

DEFINITIONS

non-equilibrium A state temporarily forced by the application of energy, such as light

femtosecond One million-billionth of a second

topological state State of matter defined by the topology of the constituent partiles; for example whether a material is a conventional insulator or a topological insulator

dissipationless Dissipationless current a flow of particles, such as electrons in an electric current, without wasted dissipation of energy

superfluid A quantum state in which particles flow without encourntering any resistance to their motion

DID YOU KNOW?

FLEET physicists from Monash and UQ were finalists in the 2020 Australian Museum Eureka Prizes for their work on turbulence in 2D flow.

‘Target identified’: teaching a machine how to identify imperfections in 2D materials

Applying machine learning to automated characterisation of atomically-thin materials

CASE STUDY

Just as James Cameron’s Terminator-800 was able to discriminate between “clothes, boots, and a motorcycle”, a FLEET study demonstrates potential for machine learning to identify different areas of interest on 2D materials.

The simple, automated optical identification of fundamentally different physical areas on these materials (e.g. areas displaying doping, strain, and electronic disorder) could significantly accelerate the science of atomically-thin materials.

Atomically-thin (or 2D) materials, including metals, semiconductors, insulators, and more-exotic quantum materials such as topological insulators, superconductors and ferromagnets, are studied by scientists around the world seeking to take advantage of their unique properties.

Materials scientists have utilised this monolayer ‘zoo’ to construct next-generation, energy-efficient electronics, batteries, memory cells and photodiodes.

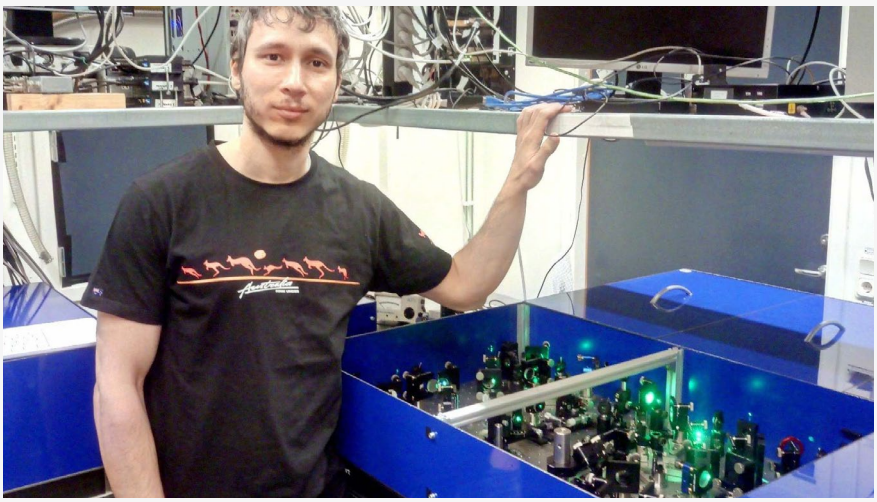
“Without any supervision, machine-learning algorithms were able to discriminate between differently perturbed areas on a 2D semiconducting material,” explains lead author Dr Pavel Kolesnichenko (Swinburne University of Technology). “This can lead to fast, machine-aided characterisation of 2D materials in the future, accelerating application of these materials in future technologies.”

However with the integration of 2D materials into next-generation technologies still involving mostly manual assembly in one-off prototypes, there is still a long way to go to reach industrial-scale production and commercialisation.

Factors that have hindered progress include lack of full control over materials fabrication, the need for experienced oversight of complex characterisation techniques, and the extreme sensitivity of monolayer materials to perturbations, many of which are introduced unintentionally.

Understanding these perturbations is a non-trivial task, as they can have a combined effect and have to be disentangled.

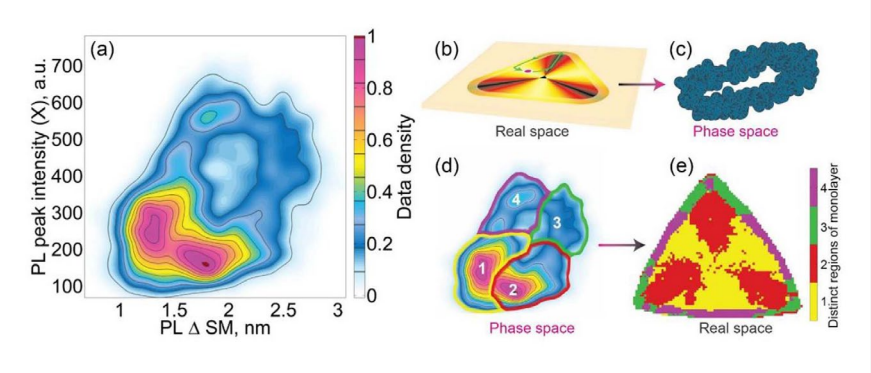
“So many factors can affect opto-electronic properties of 2D materials, including the type of substrate, additional doping, strain, the presence of wrinkles, defects, and environmental molecules – you name it,” says Pavel.



The study was led by Dr Pavel Kolesnichenko at Swinburne University of Technology (and now a postdoc at Lund University)

Pavel and Prof Jeff Davis (also at Swinburne) realised that the laborious task of 2D materials characterisation could be accomplished by machines in a rapid and automated manner.

Working with FLEET colleague Prof Michael Fuhrer (Monash University), they applied unsupervised machine-learning algorithms to characterise the semiconducting monolayer tungsten disulphide. The learning algorithms were able to discriminate between the areas on a monolayer flake affected by doping, strain, disorder, and the presence of additional layers.



Correlations between experimental parameters help identify specific imperfections causing variations in optical and electronic properties of the 2D material

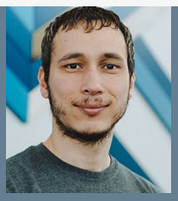
This is the first time such a systematic disentanglement of these perturbations has been performed.

The team built on previous scientific results in the field including previous work at FLEET, where they disentangled perturbations using correlated photoluminescence and absorption spectra.

In the era of data-driven science and technology, the authors hope that their research will motivate the creation of a large labelled dataset, where labels (such as 'doping', or 'strain') would be assigned by experienced researchers. This dataset would be then used to train deep neural networks to characterise 2D materials in a fraction of a second. The researchers believe that their work will help to introduce standards for characterisation of monolayer matter, approaching the moment of large-scale use of low-energy smartphones and computers in the future.

This research relates to FLEET milestone M3.1.2.
See page 19 of the strategic plan.

This study was published in *Nature Communications* in September 2021 (See publications).



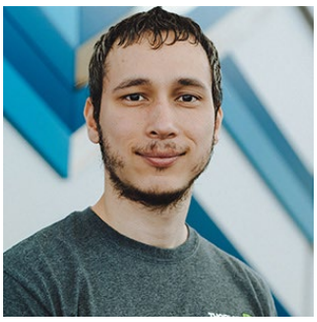
We hope this research will motivate scientists to apply similar ideas to other 2D materials and using other imaging modalities..

DR PAVEL KOLESNICHENKO (SWINBURNE)
FLEET Research Fellow

More at FLEET.org.au/machinelearning

COLLABORATING FLEET PERSONNEL

Research Fellow
Pavel Kolesnichenko
Swinburne University – alum



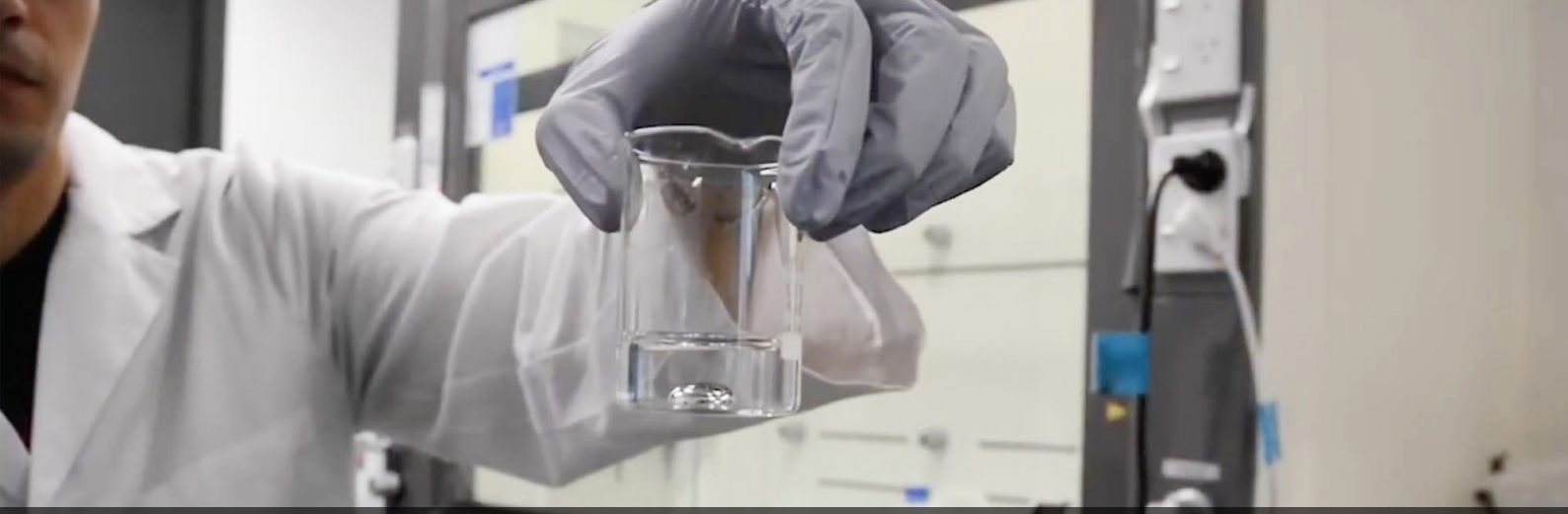
Research Fellow
Changxi Zheng
Monash University – alum

Chief Investigator
Michael Fuhrer
Monash University

Chief Investigator
Jeffrey Davis
Swinburne University

DID YOU KNOW?

Two-dimensional materials have extraordinary properties such as extremely-low resistance or highly-efficient interactions with light. However, they are inherently fragile.



Atomically-thin materials

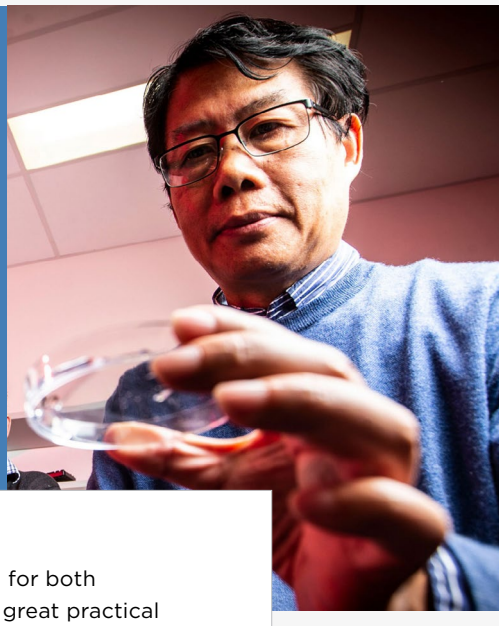
Enabling technology A

PROF XIAOLIN WANG

Leader, Enabling technology A, UOW

Expertise: design/fabrication and electronic/spintronic/ superconducting properties of novel electronic or spintronic systems such as topological insulators, high spin-polarised materials, superconductors, multiferroic materials, single crystals, thin films, nanosize particles/ribbons/rings/wires

Research outputs (Xiaolin Wang):
560+ papers
15,100+ citations
h-index 61 (Scopus)



> Novel materials are fascinating for both fundamental physics and their great practical applications in electronics.

CASE STUDY

Double-dosing induces magnetism, strengthens electron quantum oscillations in topological insulator

Read our case study

Each of FLEET's three research themes is significantly enabled by the science of novel, atomically-thin, two-dimensional (2D) materials.

These are materials that can be as thin as just one single layer of atoms, with resulting unusual and useful electronic properties.

To provide these materials, from bulk crystals to thin films to atomically-thin layers, FLEET draws on extensive expertise in materials synthesis in Australia and internationally.

The most well-known atomically-thin material is graphene, a 2D sheet of carbon atoms that is an extraordinarily-good electrical conductor.

FLEET scientists use other atomically-thin materials in their search for materials possessing the necessary properties for topological and exciton-superfluid states.

FLEET enabling technology theme A researchers at RMIT, from left: Associate Investigator Torben Daeneke, PhD Student Patjaree Aukarasereenont, former Research Fellow Ali Zavabeti

2021 HIGHLIGHTS

- Implementing dual doping effect in 3D topological insulators single crystals – (see case study)
- Achieving quantum transport and giant magnetoresistance in a new half-metal Sr_2CrMoO_6
- Discovering a new ferromagnetic material $CuCo_2S_4$
- Achieving giant anomalous Hall effect in Weyl metals Mn_3Sn
- Realising superior thermoelectric effect in nano-engineered topological insulators
- Fabricating persistent-spin candidate $BiInO_3$ films and studied surface termination and electronic structure
- Creating new phase of multiferroic $BiFeO_3$ with attractive electrochemical response
- Establishing effect of electric field on modulated phases
- Discovering intrinsic magnetic topological insulator with large band gap $MnBi_2Te_4$
- Reviewing proximity coupling of magnetism to topological insulators.

IN 2022 FLEET WILL...

- Develop new 2D ferromagnetic systems for AHE or QAHE study of topological superconductors
- Achieve giant thermoelectric effect and its application in engineered topological insulators
- Establish and study magnetocapacitance in $BiInO_3$/Ni structures
- Create ferroelectric superlattices with solitons
- Induce giant anisotropy in transport and magnetotransport in LSMO films
- Use ferroelectric/multiferroic skymrons and bimerons in BFO superlattices
- Understand electrical conductivity of ferroelectric bubble domains
- Investigate bandgap fluctuations.

DEFINITIONS

ferromagnetic Materials that can be magnetised

DID YOU KNOW?

It is estimated that there are still many thousands of atomically-thin and 2D materials still to be discovered, with applications in electronics, sensing, imagery, industrial catalysis and biomedicine.

Double-dosing induces magnetism, strengthens electron quantum oscillations in topological insulator

Double doping induces a gap for the topological surface state, harnessing massive Dirac fermions in a dual-magnetic-ion-doped topological insulator, showing extremely strong quantum oscillations in the bulk.

CASE STUDY

A University of Wollongong–led team across three FLEET nodes has combined two traditional semiconductor doping methods to achieve new efficiencies in the topological insulator bismuth-selenide.

The resulting crystals show clear ferromagnetic ordering, a large bulk band gap, high electronic mobility, and the opening of a gap of surface state, making this system a good candidate to achieve QAHE at the higher temperatures necessary for viable, sustainable future low-energy electronics.

"The combination of electronic and magnetic properties in topological systems is the keystone of novel topological devices, and one of the core projects in FLEET," says project leader Prof Xiaolin Wang (UOW). "We have proposed and successfully realised a new way to magnetise a novel electronic material – a topological insulator – by adding two different magnetic ions."

Lead author, FLEET Research Fellow Dr Weiyao Zhao (UOW)

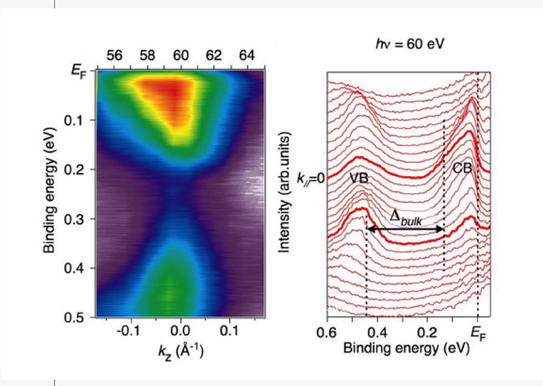
Each one of various different magnetic elements used in magnetising a topological insulator possesses its own advantages and disadvantages. However, while previous studies employed only one element, the UOW-Monash University-RMIT team found that combining two elements also combined the advantages of each.

“The dual doping strategy is thus proved viable for the growth of extremely high-quality topological insulators with both magnetism and excellent electron mobility, which are vital for low-energy electronic devices,” says the study’s lead author, Dr Weiyao Zhao.

The two key elements in the quantum anomalous Hall effect (QAHE) that ‘drives’ desirable properties in topological insulators and all related electronic technology are ferromagnetism and the topological electronic insulating property.

The collaborative FLEET study, combining expertise from UOW, Monash and RMIT pioneered a ‘dual element’ doping strategy to introduce magnetism in a topological insulator, thus improving both key elements at once.

Combining the advantages of two different doping elements, iron and samarium, results in large crystal growth, with a large surface band-gap, and huge quantum transport effect.



Angle-resolved photoelectron spectroscopy (ARPES) shows photon-energy dependence (left) and energy distribution curves (right)

Previous approaches to realise quantum anomalous Hall effect (QAHE) in a topological insulator employed doping with a single transition-metal, such as iron, to create ferromagnetism.

However, while this doping technique was successful in creating the desired magnetic ordering, the in-lattice transition metal jeopardises the desired high-mobility of the topological insulator, which in the case of low-energy electronics, defeats the purpose of using topological insulators at all!

Thus, QAHE has been realised via a transition metal doping strategy only at extremely low temperatures, which would require energy-intensive cooling. Again, this reduces the viability of such materials for future low-energy electronics.

To increase the operating temperature of QAHE, stronger magnetic interaction and higher mobility are desired.

After considering the successful elements of doping using transition metals such as iron, the research team decided to further introduce a stronger magnet, the rare earth element samarium.

The doping elements iron and samarium create the necessary ferromagnetic ordering in the crystals, which can open a massive gap at the Dirac cone of surface state. This is an essential element of achieving QAHE.

Further, the team proved that the electron mobility remains very high in the dual magnetic doped crystals. The mobility of topological insulators such as bismuth-selenide is several times faster than in classical semiconductors, such as silicon.

This research relates to FLEET milestones M1.13, M1.14 and M1.15
See page 14 of the strategic plan.

The study was published in *Physical Research* B in August 2021 (See publications).

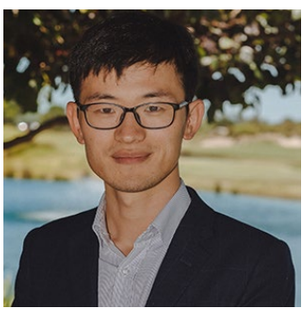
These crystals will be an ideal system to achieve QAHE at higher temperatures. And this may be a new way to cover the shortage of magnetic elements.

DR MARK EDMONDS (MONASH)
Corresponding author, FLEET Associate Investigator

More at FLEET.org.au/doubledosed

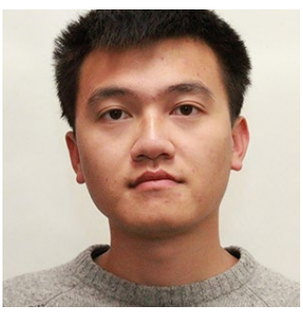
COLLABORATING FLEET PERSONNEL

Research Fellow
Weiyao Zhao
University of Wollongong/ Monash University



Research Fellow
Chi Xuan Trang
Monash University

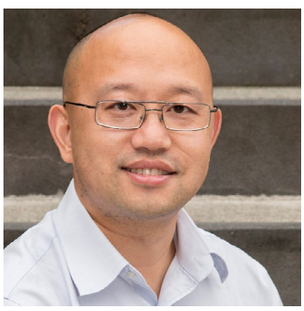
PhD Student
Qile Li
Monash University



Research Fellow
Zengji Yue
University of Wollongong

Research Fellow
Cheng Tan
RMIT University

Chief Investigator
Lan Wang
RMIT University



Scientific Associate Investigator
Mark Edmonds
Monash University

Scientific Associate Investigator
David Cortie
University of Wollongong

Chief Investigator
Xiaolin Wang
University of Wollongong

DID YOU KNOW

Topological materials represent a paradigm shift in materials science, first proposed in 1987, demonstrated in the lab in 2013 (by FLEET PI Prof Qi-kun Xue, Tsinghua), and recognised by the 2016 Nobel Prize in Physics.

Nanodevice fabrication

Enabling technology B

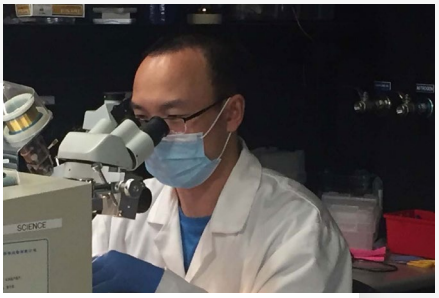
A/PROF LAN WANG

Leader, Enabling technology BA,
RMIT University

Expertise: low-temperature and high-magnetic field electron and spin transport; topological insulators; magnetic materials; spintronic and magneto-electronic devices; device fabrication; growth of single crystals, thin films and nanostructures

Research outputs (Lan Wang):
100+ papers
3500+ citations
h-index 34 (Scopus)

> FLEET teams have developed many special techniques for fabricating fancy devices based on van der Waals hetero-structures.



CASE STUDY

Transforming a layered ferromagnet for future spintronics

Read our case study

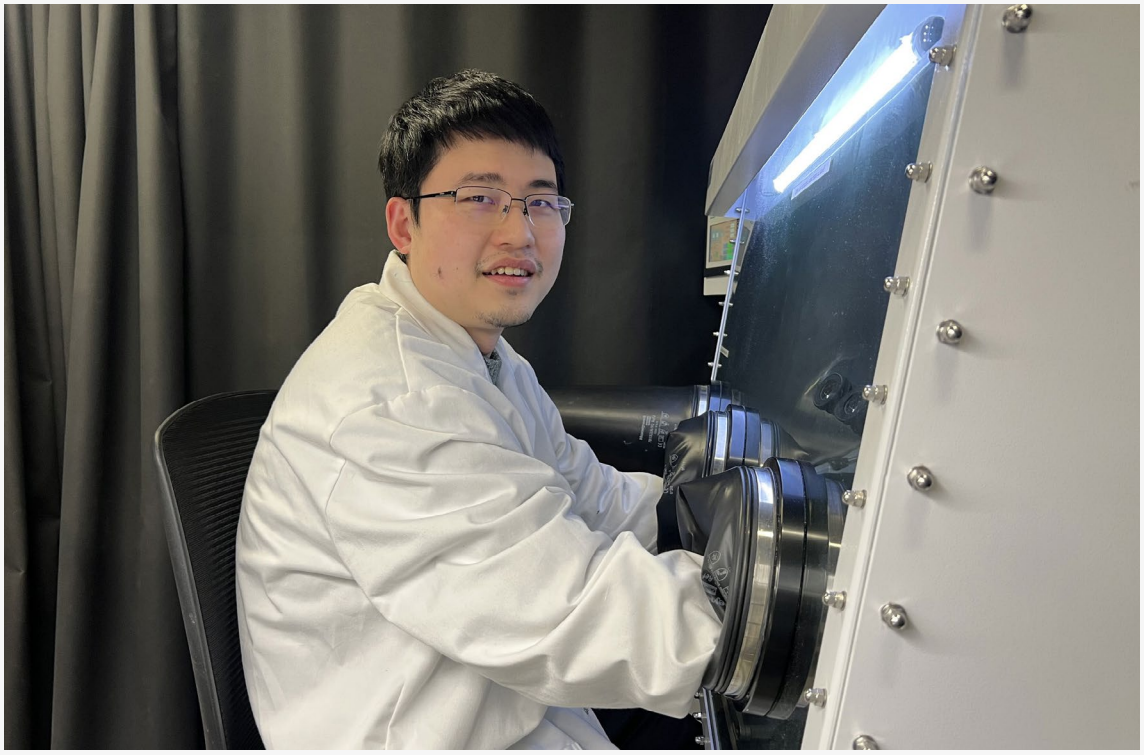
FLEET's research sits at the very boundary of what is possible in condensed-matter physics. Thus, nanoscale fabrication of functioning devices will be key to the Centre's ultimate success.

Specialised techniques are needed to integrate novel atomically-thin, two-dimensional (2D) materials into high-quality, high-performance nanodevices.

For example, successful development of functional topological transistors will require atomically-thin topological insulators to be integrated with electrical gates. And exciton-polariton condensate devices will require atomically-thin semiconductors to be integrated with optical cavities.

Nanodevice fabrication and characterisation link many of FLEET's groups and nodes. Some groups bring expertise in device fabrication, while other groups are stronger in device characterisation.

FLEET brings Australian strength in microfabrication and nanofabrication together with world-leading expertise in van der Waals (vdW) hetero-structure fabrication to build the capacity for advanced atomically-thin device fabrication.



FLEET enabling technology theme B Research Fellow Dr Cheng Tan (RMIT)

2021 HIGHLIGHTS

- Transforming F5GT vdW heterostructures for electric field control of a magnetic exchange bias – (see **case study**).
- Inducing antisymmetric spin interactions in a layered material
- Characterising surface-solidification patterns on liquid metals
- Quantifying spin transport in monolayer WTe_2 towards future spintronics.

IN 2022 FLEET WILL...

- Further confirm the electrically tunable magnetic proximity effect in vdW heterostructures
- Further investigate spin transport in vdW topological materials.

> We have nearly all the instruments we need in the Centre and we can access them after intra-Centre discussion. FLEET is a 'safe space' to be open about my research, fostering collaboration instead of being concerned about others stealing ideas. There is no competition between groups.
>
> **FLEET MEMBER SURVEY RESPONSE**

DEFINITIONS

topological insulators A topological material based alternative to the silicon-based, CMOS transistors that provide the binary switching and storage of all modern electronics

exciton Quasi-particle formed of two strongly-bound charged particles: an electron and a 'hole'

van der Waals (vdW) hetero-structure A structure made by stacking layers of different van der Waals materials

DID YOU KNOW?

FLEET researchers can stack multiple 2D layers to create novel atomically-thin van der Waals heterostructures that exhibit new properties that are not found in nature.

Transforming a layered ferromagnet for future spintronics

Transforming the layered ferromagnet Fe_5GeTe_2 for future spintronics via ultra-high charge doping

CASE STUDY

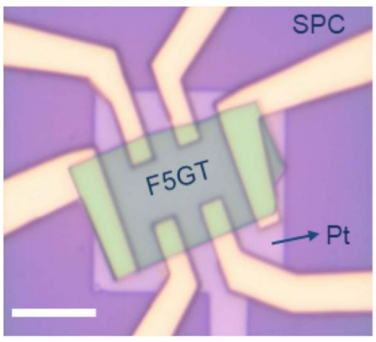
A RMIT-led, international FLEET collaboration in 2021 achieved record-high electron doping in a layered ferromagnet, causing magnetic phase transition with significant promise for future electronics.

Control of magnetism by electric voltage is vital for developing future, low-energy high-speed nano-electronic and spintronic devices, such as spin-orbit torque devices and spin field-effect transistors.

In a 2021 FLEET study, ultra-high-charge, doping-induced magnetic phase transition in a layered ferromagnet allows promising applications in antiferromagnetic spintronic devices.

The collaboration of Centre researchers at RMIT, UNSW, the University of Wollongong and partner organisation the High Magnetic Field Laboratory (China) demonstrated for the first time that ultra-high electron doping concentration can be induced in the layered van der Waals (vdW) metallic material Fe_5GeTe_2 (F5GT) by proton intercalation, and can further cause a transition of the magnetic ground state from ferromagnetism to antiferromagnetism.

The emergence of layered, vdW magnetic materials has expedited a growing search for novel vdW spintronic devices.



SP-FET transistor with F5GT flake on a solid proton conductor (scale = 10μm)

Compared to itinerant ferromagnets, antiferromagnets (AFMs) have unique advantages as building blocks of future spintronic devices. Their robustness against stray magnetic fields makes them suitable for memory devices, and some applications can operate on a lower current density.

However currently vdW itinerant antiferromagnets are still scarce.

Besides directly synthesising a vdW antiferromagnet, another possible

method towards this function is to induce a magnetic phase transition in an existing vdW itinerant ferromagnet.

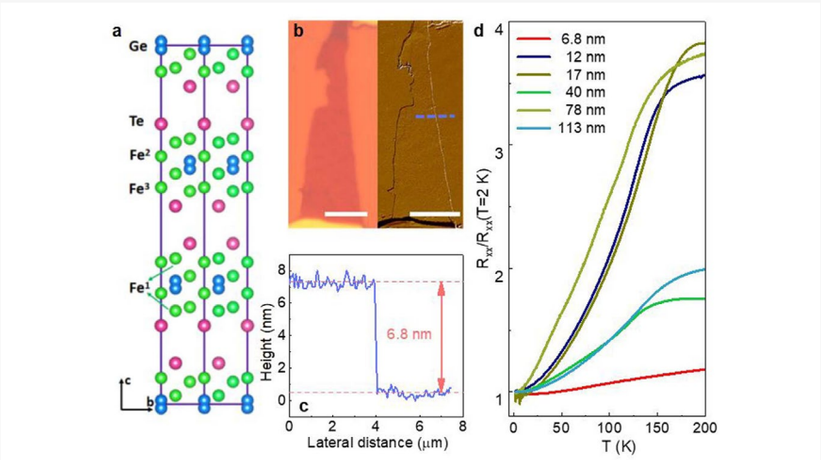
"We chose to work with newly-synthesised vdW itinerant ferromagnet Fe_5GeTe_2 (F5GT)" says the study's first author, FLEET Research Fellow Dr Cheng Tan (RMIT).

"Our previous experience with this material enabled us to quickly identify and evaluate its magnetic properties, and we knew Fe_5GeTe_2 could be sensitive to local atomic arrangements and interlayer stacking configurations, meaning it would be possible to induce a phase transition in it by doping," Cheng says.

The team first investigated the magnetic properties in Fe_5GeTe_2 nanosheets of various thicknesses by electron transport measurements.

However, the initial transport results also showed that the electron density in Fe_5GeTe_2 was high as expected, indicating that it is hard to modulate magnetism by traditional gate voltage due to the electric-screen effect in metal.

"Despite the high charge density in Fe_5GeTe_2, we knew it was worth trying to tune the material via protonic gating, as we have previously achieved in Fe_5GeTe_2 (in a 2020 paper in Physical Review Letters), because protons can easily penetrate into the interlayer and induce large charge doping, without damaging the lattice structure," says co-author Dr Guolin Zheng (also at RMIT).



Crystal structure and initial characterization of F5GT

The team are seeking to build an improved form of the transistor, the switches that provide the binary backbone of modern electronics.

A solid protonic field-effect transistor (SP-FET) switches based on insertion (intercalation) of protons; this method has been demonstrated to be very powerful in tuning thick metallic materials, which are very difficult to modulate via traditional techniques because of screening effects.

By fabricating an SP-FET with Fe_5GeTe_5, the team were able to dramatically change carrier density and change the material's magnetic ground state. Theoretical calculations confirmed the experimental results.

"All the samples show that the ferromagnetic state can be gradually supressed by increasing proton intercalation," says Cheng. "Again, this demonstrates that our protonic gate technique is a powerful weapon in electron transport experiments, and probably in other areas well."

This research relates to FLEET milestones M1.6, M1.14 and M1.17
See page 19, 14, 15 of the strategic plan.

The study was published in *Nano Letters* in June 2021 (See publications).

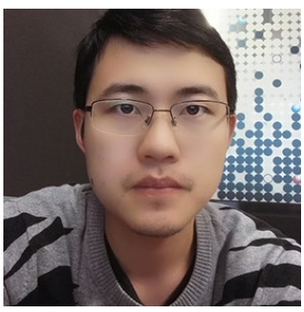
The success of realising an AFM phase in these metallic vdW ferromagnet nanosheets constitutes an important step towards vdW antiferromagnetic devices and hetero-structures that operate at high temperatures.

A/PROF LAN WANG (RMIT)
Co-author FLEET Chief Investigator

More at FLEET.org.au/doped ferromagnet

COLLABORATING FLEET PERSONNEL

Research Fellow
Cheng Tan
RMIT University



Research Fellow
Guolin Zheng
RMIT University

PhD student
Nuriyah Aloufi
RMIT University – alum

PhD student
Sultan Albarakati
RMIT University

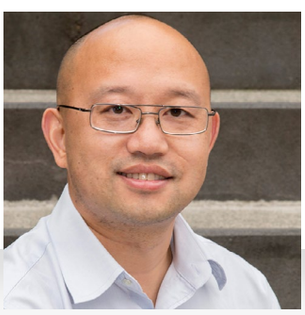
PhD student
Meri Algarni
RMIT University

Chief Investigator
Dimitrie Culcer
UNSW

Chief Investigator
Xiaolin Wang
University of Wollongong

Partner Investigator
Mingliang Tian
High Magnetic Field Laboratory, CAS (China)

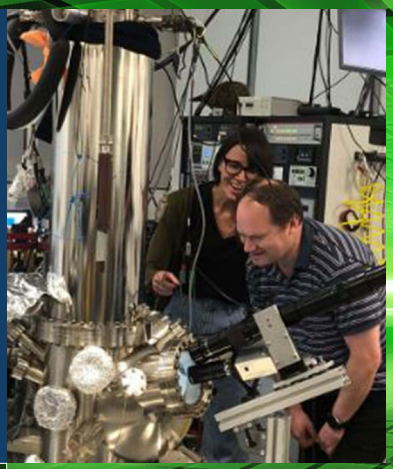
Chief Investigator
Lan Wang
RMIT University



DID you KNOW

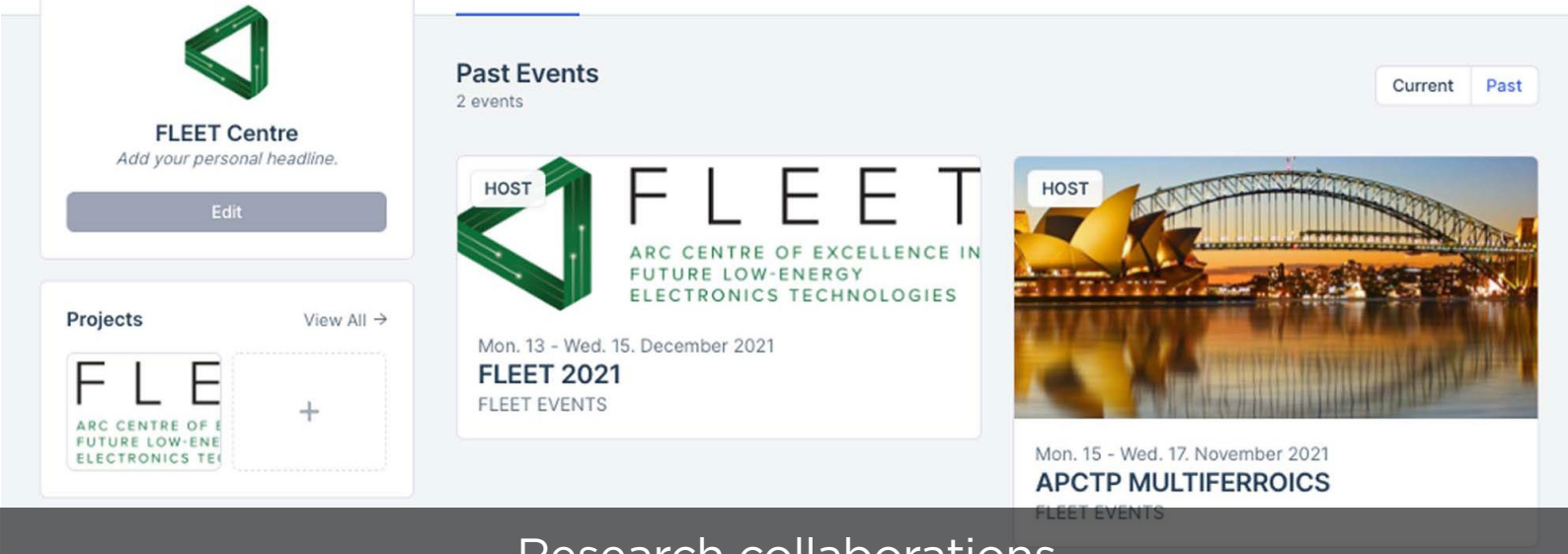
Van der Waals (vdW) materials are those held together by vdW forces – weak bonding forces between nearby molecules. These same forces are what allows a gecko's feet to stick to the wall as it climbs.

COLLABORATE



FLEET brings together a network of leading national and international experts to fulfil the Centre's mission

COLLABORATIVE EFFORTS



Research collaborations

FLEET's extensive network of 23 leading national and international research partners is key to fulfilling the Centre's mission.

FLEET links over 200 researchers across participating nodes with 23 national and international partner organisations, and is building links with an even wider scientific network. As evidence of the growing collaborations within the Centre, a sixth of publications in 2021 represented cross-node collaborations, compared with only 3% in the Centre's first year.

With 2021 seeing a continuation of Covid-related restrictions on travel, both within Australia and internationally, FLEET responded by:

- Continuing 2020's expanded series of research seminars
- Building international links in the Americas (trans-Pacific seminars) and Asia-Pacific (multiferroics conference) – see Case study
- Proactively seeking opportunities to partner with other science organisations on science, equity and development – see Professional collaborations
- Inviting international Partner Investigators and associate investigators to the Centre's end-of-year workshop, with approximately 19 attending talks and online poster sessions.

CASE STUDY

Maintaining international research connections across Asia-Pacific, Americas

Read our case study

Links with FLEET's New Zealand partner the MacDiarmid Institute were strengthened by adding a new Partner Investigator Dr Simon Granville who has been actively working with FLEET chief investigators at Monash, RMIT, Wollongong and UNSW. When borders allow, FLEET Chief Investigator Prof Jared Cole will begin a Royal Society of NZ fellowship to work with MacDiarmid, building up trans-Tasman links in device modelling and advanced materials simulation.

FLEET WILL:

- Establish strong, lasting links between Australian and international science communities
- Maximise ongoing benefit to Australia from established FLEET networks and linkages

FLEET is building synergies between several research communities in Australia. The percentage of cross-node publications has grown from 3% (2017) to 16% (2021), reflecting the importance of inter-node research in FLEET.

Publications involving multiple CIs, AIs, PIs and/or nodes make up 61% of all FLEET publications.

Since its establishment the Centre has forged links with 39 new research organisations with aligned research interests; these have joined the initial FLEET network of 20 national and international institutions.

FLEET's long-time collaborator Dr Simon Granville joined the Centre in 2021 as a new Partner Investigator. Simon is a Principal Investigator at FLEET's NZ partner organisation MacDiarmid, where he leads the Institute's Future Computing project to control electron transport and spin through superconductivity and topology.

> I have been able to network with people from different universities and develop new skills that are transferable.
>
> **FLEET MEMBER SURVEY RESPONSE**

HOSTING RESEARCH SEMINARS

FLEET maintained its Centre-wide seminar series with eight research seminars delivered in 2021 scheduled in and around 14 transpacific colloquia, and the expanded node 'journal club' meetings, which now regularly involve multiple interstate Centre attendees.

The research seminar series features a mixture of new and existing investigators and collaborators, as well as breaking research findings from FLEET research fellows.

In addition to keeping members updated with new progress and developments in the field, these talks strengthen partnerships between Australian and international science communities, and establish connections with new collaborators. A total of 300 attendees joined in to hear from Centre and visiting speakers, including around 20% from outside FLEET. The significant proportion of external, international attendees at Centre talks speaks to the seminars' impact in communicating FLEET's mission and research to the wider international research community.

Except when confidential, unpublished information was shared, talks were recorded and shared via YouTube and social media for a wider audience.

While Covid restrictions kept all FLEET's research seminars online in 2021, online delivery facilitated Centre cohesion, inclusiveness and greater awareness of the breadth of FLEET research by enabling greater participation of FLEET members across all its nodes and external participants.

> I love the invitations to join seminars and webinars and journal clubs across the country! These are only possible since Covid.
>
> **FLEET MEMBER SURVEY RESPONSE**

Professional collaborations

Building links with the Australian and international science communities

To counter Covid's ongoing challenges to in-person collaborations, FLEET continued to proactively seek out opportunities to partner with other science organisations to further the reach of Centre-relevant science, to advance equity issues and to develop future leaders.

For example, in 2021 FLEET:

- Sponsored a poster session and promoted science at the AIP Summer Meeting with the Australian Institute of Physics (AIP)
- Continued the transpacific colloquia series with the Joint Quantum Institute (University of Maryland) and Monash University School of Physics and Astronomy
- Co-hosted research seminars with ANSTO, and the ARC Centres for Exciton Science and Transformative Meta-Optical Systems (TMOS)
- Delivered the third year of FLEET's Future Electronics Year 10 unit with John Monash Science School (JMSS)
- Presented Immersion Day workshops for Year 10 and 11 students with JMSS and Monash Faculty of Science
- Hosted work experience Year 10 students from McKinnon High School
- Worked with Women in Leadership Australia on leadership training for four FLEET participants
- Worked with semiconductor company Silanna on an industry-engagement seminar
- Ran Active bystander training with the Monash University Respectful Communities unit
- Undertook industry-engagement and research-translation training (Base program) with Cruxes Innovation
- Presented the National Science Quiz with ARC Centres for Mathematical and Statistical Frontiers (ACEMS), Exciton Science, Gravitational Wave Discovery (OzGrav), Advanced Molecular Imaging, and Synthetic Biology, with Inspiring Australia, and took on legacy leadership of this valuable ACEMS outreach program to ensure its long-term viability beyond the life of that centre
- Worked with the Asia Pacific Center for Theoretical Physics (APCTP) and Association of Asia Pacific Physical Societies (AAPPS) to co-present multiferroics conference, with government sponsorship from the Australia–Korea Foundation

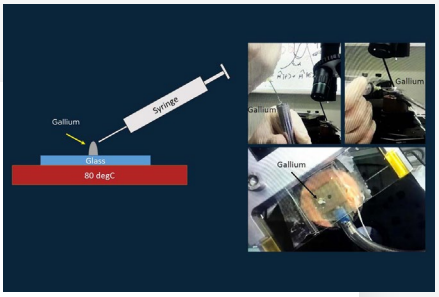
- Developed ECRs' transferrable skills in continuing Idea Factory collaboration with the ARC Centre for Engineered Quantum Technology (EQUS)
- Trained Centre members on media engagement and presentation skills, with the ARC Centres for Mathematical and Statistical Frontiers (ACEMS) and Fragment-Based Design (CFBD)
- Implemented FLEET's new research-translation program, developed and guided by EQUS, including appointing a new translation manager who works across both Centres.

Planned, collaborative in-person events with Monash Tech School and Emmanuel College were necessarily delayed by Covid, but the groundwork done will permit quick implementation (circumstances permitting) in 2022

CASE STUDY

Creative, online lab demonstrations maintain international collaborations

Read our case study

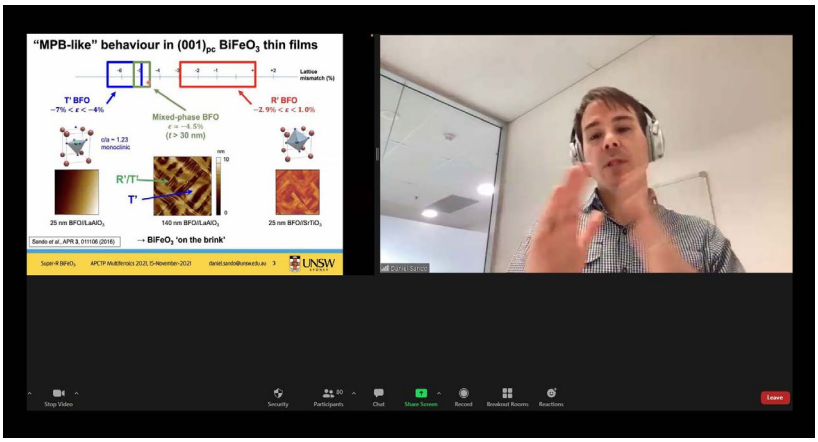


ASIA-PACIFIC WORKSHOP ON MULTIFERROICS

With Australian–US links being strengthened by FLEET's transpacific series, attention turned in 2021 to similarly fortifying links with important novel materials and physics research communities in Asia.

To build better links with the region, FLEET brought the Asia Pacific Center for Theoretical Physics (APCTP) conference series to Australia for the first time. In 2021, the conference focused on FLEET Theme 1 materials – specifically, multiferroic materials.

The 2021 Multiferroics conference built on FLEET's previous success hosting major events: the International Conference on Two-Dimensional Materials and Technologies (ICON2D-Mat) in 2018 and Spontaneous Coherence in Excitonic Systems (ICSCE) in 2020, and co-hosting events in Germany and Italy.



FLEET Research Fellow Dr Daniel Sando presents at Multiferroics conference

Around 150 researchers from across the Asia-Pacific region joined FLEET online in November 2021 for the 12th APCTP Workshop on Multiferroics; 27 talks and a dozen posters covered materials that exhibit more than one type of built-in order (e.g. magnetism and ferroelectricity).

An extremely strong field of speakers included some of the biggest names in multiferroics from Australia, China, Japan, Korea, Singapore and the US.

FLEET Chief Investigator Prof Jan Seidel (UNSW) and FLEET-UNSW node coordinator Cecilia Bloise formed the core, local organising team.

Perennial 'hot topics' around the compatibility between ferroelectricity and magnetism were explored, including multiferroic domain engineering, electromagnon excitation and manipulation, and artificial multiferroic hetero-structures.

Recent additions include multiferroic van der Waals materials and topological defects such as domain walls and skyrmions in multiferroics.

As well as co-sponsorship between FLEET and the APCTP, government support for the event was received from the Australia–Korea Foundation, and publicity and communications support coordinated with the Association of Asia Pacific Physical Societies (AAPPS).

> The multiferroic conference was an opportunity to explore the latest discoveries in multiferroic physics and materials, which is one of the most rapidly developing areas in condensed-matter research today. It was also a welcome opportunity to strengthen links with colleagues in Asia.
>
> **PROF JAN SEIDEL (UNSW)**
> *Conference Chair FLEET Chief Investigator*

More at FLEET.org.au/multiferroics

TRANS-TASMAN COLD ATOMS SEMINAR SERIES

A monthly seminar series launched in 2021 unites cold atoms researchers from Australia and New Zealand.

Co-hosted by FLEET and the Centre of Excellence for Engineered Quantum Systems (EQUS), the series facilitates ongoing discussions and collaboration via Zoom, with physical attendance in individual institutions as Covid has allowed.

Seven seminars were convened in the first year of the series.

The cold-atoms series is coordinated by FLEET Chief Investigator Prof Matt Davis (UQ)

More at FLEET.org.au/coldas

Maintaining international research connections across Asia-Pacific, Americas

Keeping research communities connected during Covid

CASE STUDY

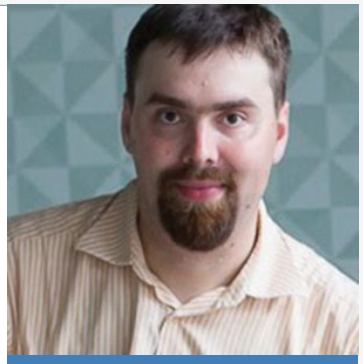
Ongoing restrictions on international visits, which have traditionally sparked and fuelled research collaborations, have pushed FLEET to find new ways to connect.

Some positives have surfaced amid the negative impacts of Covid-19 travel bans on science collaboration, including the expansion in videoconferencing allowing researchers from geographically isolated regions to connect.

FLEET has brought three international conference series to Australia for the first time, hosting the International Conference on 2D Materials and Technologies (2018), International Conference on Spontaneous Coherence in Excitonic Systems (2020) and APTC Workshop on Multiferroics (2021).

US–AUSTRALIAN TRANSPACIFIC CONDENSED-MATTER TALKS

In 2020, together with Centre partners at the Joint Quantum Institute (University of Maryland) and Monash University, FLEET inaugurated and hosted a new transpacific colloquium series presenting novel developments in condensed-matter and cold-atom physics to maintain and strengthen connections between physics communities in Australia and North America.



Dr Dmitry Efimkin (Monash) leads the transpacific colloquia organising committee

In 2021, the series hosted 14 colloquia (a significant increase from seven in 2020) with speakers from the following organisations in North America: California Institute of Technology, Columbia University, Harvard, McGill University, Ohio State University, Rutgers University, Stanford University and the University of Texas. Gender mix has been an ongoing focus, and over 40% of the speakers in 2021 were female.

The series' organisation committee, led by FLEET Associate Investigator Dr Dmitry Efimkin (Monash), who directs series strategy, coordinates publicity and manages speaker recruitment seeking expertise specific to FLEET goals and research interests.

The colloquia covered topics from all FLEET research themes, including:

- Topological materials
- Moire superlattices
- Quantum stochastic resonance
- Dark matter challenges in solid state physics
- Non-Hermitian physics with exciton-polaritons
- Inverse-designed integrated photonics
- Domain/skyrmion-bound surface states on magnetic topological insulators
- Tunable edge states in vdW materials
- Quantum simulators
- Topological physics at light–matter interface
- Anomalous Hall effect in non-magnetic conductors
- Programmable quantum materials.

The 14 colloquia in 2021 attracted more than 530 Centre members and another 120 external participants.

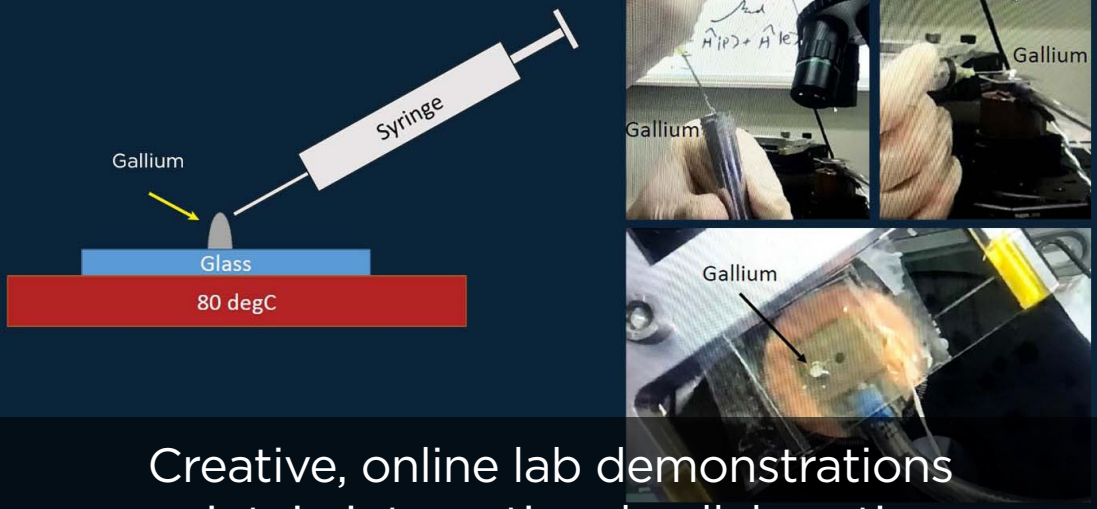
The transpacific series represents one of Covid's 'silver linings': an improvement in the way the Centre operates that has been embedded as the 'new normal' going forward.

Regardless of travel policies, the US–Australia Transpacific Colloquium series will continue, with alternative partners being sought to assure its long-term viability. The first four speakers in 2022 have already been confirmed.

FLEET provides a wide variety of seminars with leading experts that allow members to communicate and collaborate with some of the world's best in related subject areas.

FLEET MEMBER SURVEY RESPONSE

Read more
FLEET.org.au/
trans-pacific



Creative, online lab demonstrations maintain international collaborations

Finding clever solutions to Covid-based travel restrictions

CASE STUDY

FLEET researchers have live-streamed experiments from the lab in Australia to US collaborators and other FLEET nodes, reciprocated by a US-hosted workshop.

How does global research collaboration work while Covid-19 still prevents international in-lab visits?

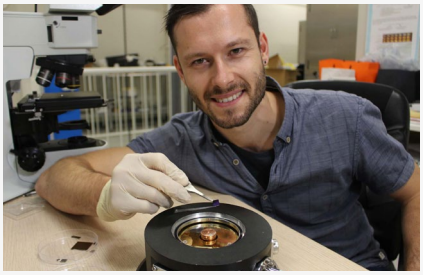
A FLEET collaboration in 2021 found a creative solution, running in-lab demonstrations of new quantum technologies across multiple universities on two continents.

FLEET's Matthias Wurdack (ANU) and Dr Semonti Bhattacharyya (Monash) were able to consult with researchers in the New York lab of FLEET Partner Investigator Prof Jim Hone (Columbia University), demonstrating new techniques developed on either side of the Pacific Ocean.

Columbia postdoc Dr Sanghoon Chae initiated the transfer of knowledge by asking for more information on the FLEET's recently published gallium-oxide 'quantum armour' technique (see case study).

This contact initiated two online demonstrations, one on each side of the globe.

Matthias and Semonti conducted a demonstration for the Columbia University team, run from Matthias's lab at ANU, demonstrating the new synthesis and transfer techniques.



"The last year has honed all of our skills in remote and online communications"... FLEET PhD student Matthias Wurdack (ANU)

"Sanghoon's technique will give us access to high-quality monolayers of these materials"... FLEET Research Fellow Semonti Bhattacharyya (Monash)

The scalable FLEET technique will help Prof James Hones' group to realise electronic and opto-electronic devices with large functional areas based on two-dimensional materials. "The greatest advantage of FLEET technique is that it is easy to fabricate in large scale," explains Sanghoon. "Normally, dielectric deposition requires semiconductor fabrication tools, but Matthias's technique only needs heat stage and silicon rubber. This shift in thinking came as a big shock to us."

The Columbia team then ran a corresponding workshop for 15 FLEET attendees from Monash, Swinburne, ANU and RMIT, demonstrating their new monolayer TMDC exfoliation technique, which will directly benefit FLEET research.

"TMDCs are at the heart of theme 2 research at FLEET. Being able to adopt Sanghoon's technique will give us access to high-quality monolayers of these materials; this is essential to achieve scalability in future low-power electronics," explains Semonti.

"The whole process was a very nice demonstration of researchers being creative in the face of challenges – the heart of science," says Dr Stuart Earl (Swinburne), who attended Sanghoon's training session.

"It was great how Semonti and Matthias got the broader Centre involved. The Covid pandemic has shown how much smaller the world has grown, and made us realise that we're much more of a closely-linked community thanks to the ready availability of our international colleagues (via online communication tools) than we previously appreciated."

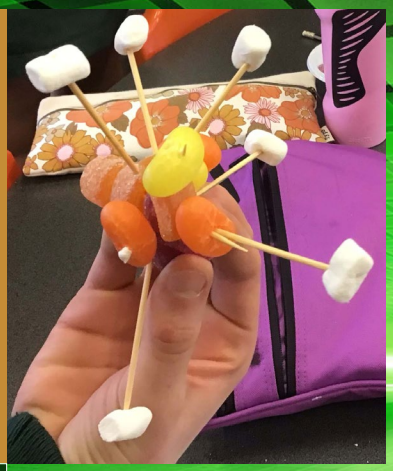
"

The last year has honed all of our skills in remote and online communications. Live-streaming the fabrication steps of the new process from our lab at ANU meant that we could directly address questions from the researchers at Columbia during the process.

MATTHIAS WURDACK (ANU)
FLEET PhD candidate

Read more
FLEET.org.au

ENGAGE WITH FLEET



FLEET has an extremely ambitious program of STEM outreach and communication, engaging Australians with science – from school children to the public to policymakers

ENGAGE WITH FLEET

BLOGS	95
PRESS RELEASES	30
MENTIONS IN ONLINE MEDIA	412
NON PEER REVIEWED ARTICLES	25
PRINT ARTICLES	21
RADIO INTERVIEWS	2
PARTNER/ NODE NEWS STORIES	24

AVERAGE MONTHLY UNIQUE PAGE VIEWS

AVERAGE MONTHLY NEW USERS VISITS FLEET.ORG.AU

1412

TWITTER FOLLOWERS **274 NEW**

722

FACEBOOK FOLLOWERS **78 NEW**

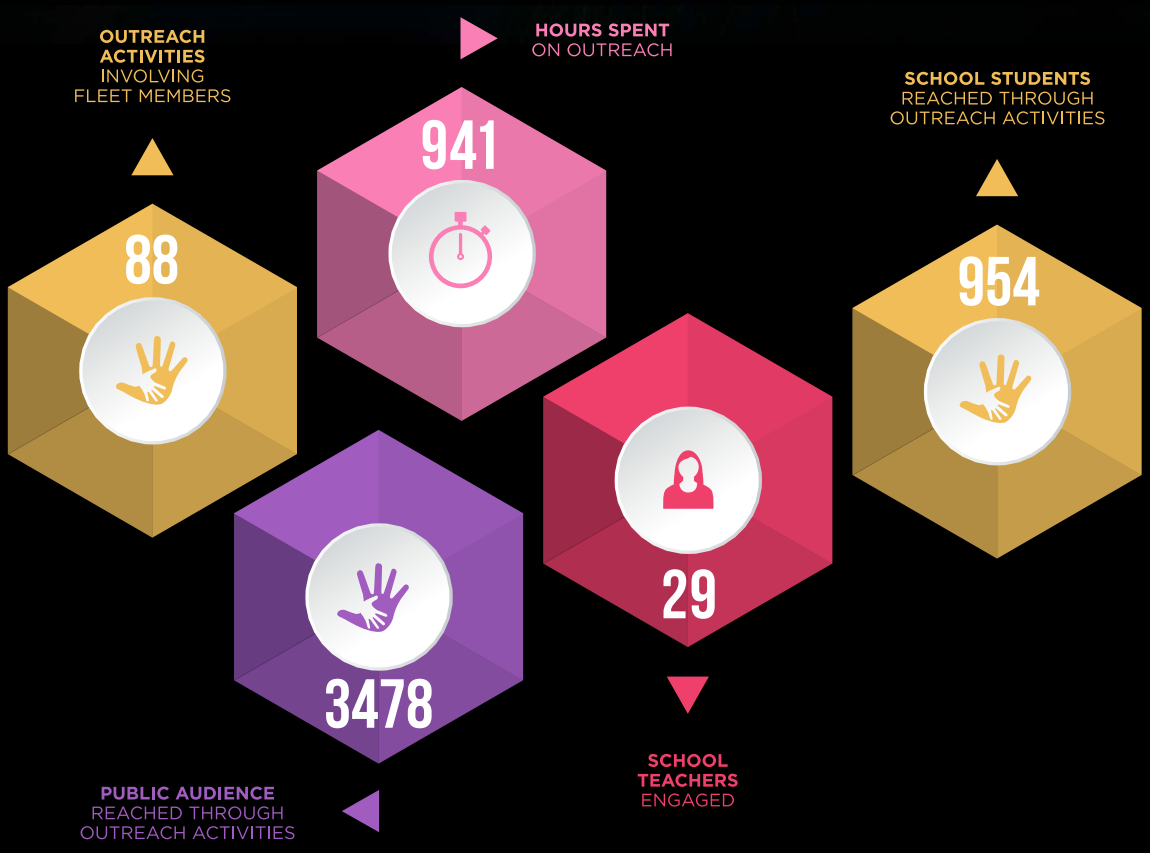
1080

LINKEDIN FOLLOWERS **338 NEW**

51,957

VIEWS OF **FLEET YOUTUBE** CHANNEL

OUTREACH


OUTREACH ACTIVITIES INVOLVING FLEET MEMBERS
88
HOURS SPENT ON OUTREACH
941
SCHOOL STUDENTS REACHED THROUGH OUTREACH ACTIVITIES
954
29
SCHOOL TEACHERS ENGAGED
3478
PUBLIC AUDIENCE REACHED THROUGH OUTREACH ACTIVITIES

Spreading a passion for science: Outreach

FLEET shares the responsibility to increase the participation of students in science, and to increase the number of girls and women participating in physics, chemistry and engineering.

FLEET's outreach activities improve public awareness of FLEET research and scientific literacy among school students. FLEET members get a greater appreciation of their audience and their values and how to effectively communicate with them.

FLEET focuses significant efforts on science outreach, with the aim of:

- Increasing the participation of students in science and physics
- Increasing awareness, passion and appreciation for science in the general public
- Improving the outreach skills of FLEET members
- Facilitating public discussion of FLEET-specific research.

FLEET has an innovative and ambitious approach to outreach, with all FLEET members (from PhD student to director) required to do at least 20 hours of outreach each year. Members value outreach, seeing it as excellent training in science communications and a competitive advantage for their CVs.

FLEET's outreach program also represents significant transferable-skills development, with members honing pitch and communications skills on students or public, and later applying the same skills in conversations with future collaborators or decision-makers.

CASE STUDY

Engaging public conversations at Melbourne Knowledge Week

Read our case study

> In communicating with public I learnt that sometimes it's better to leave out information, if it helps get the message across. You don't have to explain the entirety of something for someone to get to grips with why it's useful, or important in the wider scope.
>
> **FLEET PARTICIPANT**
> **MELBOURNE KNOWLEDGE WEEK**

FLEET OUTREACH HIGHLIGHTS IN 2021

- Engendering greater awareness of FLEET research at **Melbourne Knowledge Week**
- Inspiring students (particularly girls) to study physics with ongoing FLEET-JMSS **Future Electronics unit**
- Successfully road-testing atomic and electrical learning methods at **Ashburton Primary School pilot**.

IN 2022 FLEET WILL...

- Build engagement in **Ask the Physicists Facebook page**
- Begin workshops for students and teachers using new teacher resources on light and electricity
- Develop a third teacher resource on energy
- Re-develop more home-science experiments towards use in classrooms
- Evaluate each outreach activity to understand impact on awareness and scientific literacy
- Target outreach to disadvantaged primary and secondary students
- Lead first year of new legacy committee for **National Science Quiz**
- Conduct science-based story time event for book week.

CASE STUDY

Igniting a spark for learning in primary school students

Read our case study

2021: ANOTHER CHALLENGING YEAR FOR OUTREACH!

Back in 2019, after a remarkable achievement in reaching over 10,000 students, FLEET voluntarily raised its outreach targets tenfold, to 2500 students, 75 teachers and 5000 public members.

These ambitious targets have certainly proven challenging with Covid subsequently causing the cancelling of most public events, and banning most in-class or in-lab visits.

However, FLEET remains extremely proud of our achievements in science outreach in 2020–21.

While Covid prevented in-person incursions to schools and excursion to FLEET labs, FLEET has developed new, in-depth teacher resources, beginning with a unit on light and optics, and another on conductors, insulators and electricity. The third teacher resource, on energy, will be developed in early 2022. A new, teacher-facing structure on the FLEET website improves access to these teacher- and student-based resources. FLEET.org.au/schools is now the 'go to' page of all outreach resources to schools.

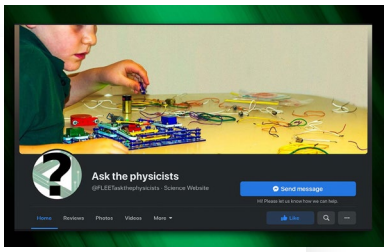
Greater content depth and extra teacher resources have been added to FLEET's home science series of experiments, which provide science opportunities for young children and adults, making science easy, accessible and relevant. Additional content includes worksheets, critical thinking exercises, graphics and explanatory videos. This effort will continue with other home-science experiments in 2022.

FLEET is leveraging social media to improve engagement with students and teachers via a new 'Ask the physicists' Facebook page where students' and teachers' questions are answered by FLEET members. The 'Ask the physicists' page is also a useful platform for updating followers about FLEET outreach and schools resources.

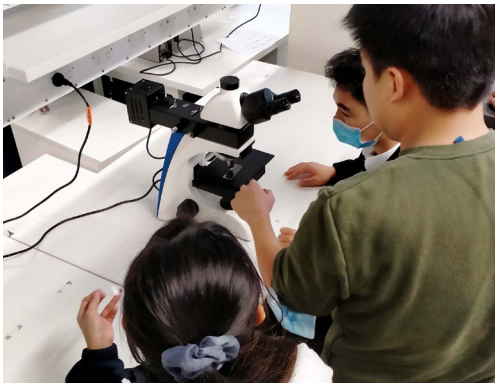
CASE STUDY

Engaging Q&A: FLEET's 'Ask the physicists' page

Read our case study



Three face-to-face events were conducted opportunistically between lockdown periods, with 13 FLEET volunteers meeting the public at Melbourne Knowledge Week (see case study), a FLEET presence at the John Monash Science School (JMSS) Immersion Day, and a 'fireside chat' briefing for end user community organisation the Melbourne Computer Club (see case study).

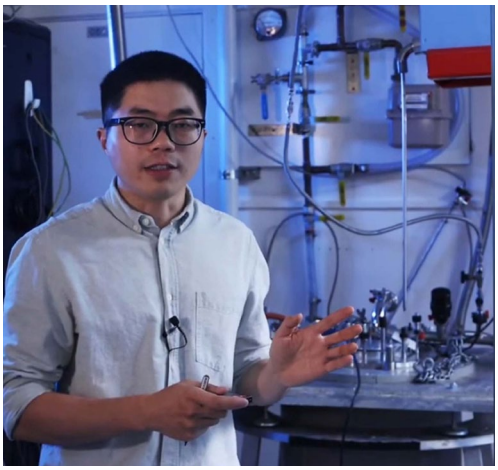


FLEET members running hands-on graphene exercises during JMSS Immersion Day

While some planned face-to-face events were cancelled (school incursions, work experience, Science in the City, and New Scientist Live), others could be moved online.

FLEET worked with the John Monash Science School to deliver the ongoing Future Electronics unit online, with FLEET presenters and teachers managing the significant challenge of engaging students at home. The first follow-up evaluation of this unit explored impact on past students, with encouraging results regarding engagement and female role models (see case study).

Also moving online, FLEET participated in the National Science Quiz, in collaboration with ARC Centres for Mathematical and Statistical Frontiers (ACEMS), Exciton Science, Gravitational Wave Discovery (OzGrav), Advanced Molecular Imaging, and Synthetic Biology, with Inspiring Australia.



Explainer videos for scientific techniques build members' communication skills with 'higher level' science outreach

In 2021 FLEET piloted methods to evaluate the impact of online incursions to schools (see case study), which with minor improvements will provide valuable insights into the impact of FLEET outreach in science literacy and engagement.

To help members reach the Centre's recommended 20 outreach hours per year while Covid posed such significant challenges, FLEET compiled and promoted a 'suite' of options, from writing sections for FLEET Schools, updating and adding depth to existing home-science experiments and developing new home-science content linked to the Australian school curriculum. While performing almost 1000 hours of outreach in 2021 (target 1500), FLEET members:

- Added new content to home-science experiments
- Fine-tuned their skills in science outreach and communication, including media training (see case study) and pitching to industry
- Presented their science in Three Minute Science (with FLEET's Mitko Oldfield winning the Monash University competition) and Visualise Your Thesis
- Created a 'video toolkit' series of explainer videos for the facilities and techniques used by FLEET's team at UNSW, including the most-useful tools in materials synthesis and study
- Wrote 'tools of the trade' articles describing scientific techniques for Nature, among 25 non-peer reviewed pieces of writing in 2021
- Explained their PhDs on radio for RRR show Einstein a Go-Go's 20 PhDs in 20 minutes.

> FLEET provides great numbers of interesting outreach opportunities, and therefore I can always find my preferred scopes to contribute in.
>
> **FLEET MEMBER SURVEY RESPONSE**

FLEET's superconducting mobius strip has been one of the Centre's most effective science outreach tools

Despite a year of Covid restrictions, FLEET directly reached 29 teachers against a target of 75 (not including teachers reached via new, teacher-oriented Facebook and online platforms). In addition the Centre reached almost 1000 school students (target 2500) and 3500 members of the public (target 5500).

As part of FLEET's strategy to reach a wider audience, 12 FLEET volunteers have joined CSIRO's STEM Professionals in School program that aims to bring science outreach to remote and regional schools and is commencing in 2022.

A team of five FLEET members are working on a new interactive exhibit, planning ahead for the resumption of public events. The portable laser-holograph machine will enable the public to help create, and then take home, a holographic image of themselves. A pilot demonstration is planned for early 2022.

> FLEET outreach is unusual in that it is aimed at both improving science knowledge in the public (e.g. events facing general public and school incursions / excursions / videos) but also in improving members' science-communications skills.
>
> **FLEET MEMBER SURVEY RESPONSE**

CASE STUDY

Outreach legacy: Accepting the baton for National Science Quiz

Read our case study

LEGACY

FLEET WILL:

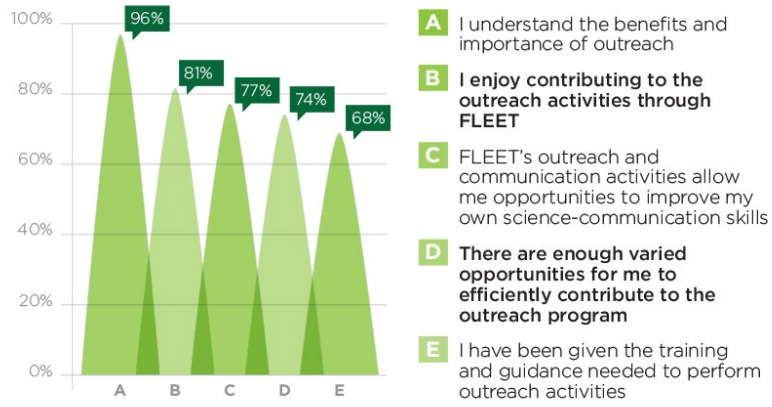
- Promote science literacy in schools
- Improve public awareness of quantum science, electronics and sustainable computing

OUTREACH WITH IMPACT: EVALUATING IMPACT OF FLEET'S OUTREACH ACTIVITIES

FLEET's public and schools outreach activities seek to promote public awareness and literacy of FLEET science by contributing to public scientific literacy, raising awareness and understanding of FLEET science among students and teachers, and improving public awareness of FLEET (and adjacent) areas of research.

But how do we know if we are achieving our objective? What impact are we achieving on awareness and literacy in our target audiences?

Evaluation is built into FLEET outreach: each outreach event is designed from the outset to allow evaluation, assessment and measurement against Centre goals.



96% of members understand the benefits of outreach, according to the Centre's 2021 Centre-wide survey

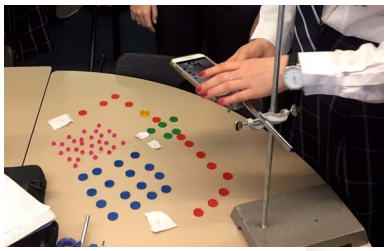
Major outreach evaluation projects in 2021 included:

- **Melbourne Knowledge Week** Entry and exit surveying confirmed a positive effect on visitors' appreciation and awareness of physics (see case study)
- **Ashburton Primary School** electricity and atoms workshop. Comparison of students' understanding before and after hands-on exercises revealed the 'surprising power of the periodic table' (see case study)
- **FLEET/JMSS Future Electronics unit** Surveying found the unit positively affected students' consideration of further physics studies, and that the participation of female scientists enabled female students to see a place for themselves in physics (see case study).

CASE STUDY

Student surveys confirm benefits of FLEET Future Electronics unit

Read our case study



Sharing FLEET research: communication

Communicating FLEET research and events, supporting Centre strategic priorities, internally and externally

Centre communications cover both internal and external needs. While the two audiences are very different, base content is used across both areas, to maximise efficiency.

FLEET's communications functions include:

- Internal communication to maintain a cohesive Centre
- Informing the Australian public of the benefits being gained from research funded by the Australian Research Council (ARC)
- Supporting FLEET's outreach functions to build a more science-aware public
- Appropriately communicating FLEET's research outputs to different audiences, from the general public to the research community and potential collaborators, industry partners and end users
- Building the transferable communications skills of FLEET members.

Many 2020 Centre communication initiatives in response to Covid-related challenges to internal cohesion have remained valuable in 2021, and will likely become an ongoing part of Centre operations after the end of the pandemic.

These include:

- Maintaining a higher number of internal Centre seminars (eight in 2021)
- Sending weekly email digests, including Zoom links, to members and affiliates to summarise Centre and relevant online events
- Extending the use of online virtual meetings to alternative platforms Kumospace and MeetAnyway to allow organic discussions and poster sessions, including at the Centre's annual workshop
- Boosting the transpacific series of condensed-matter talks (14 talks in 2021) and running the Multiferroics conference to maintain links with international research communities (see case study)
- Continuing to seek out opportunities to partner with other science organisations in delivering 'Covid safe' science and training (see Professional Collaborations)
- Promoting FLEET researchers' work via increased numbers of research blog posts and press releases (30 in 2021).

CASE STUDY

Maintaining cohesion:
Centre meetings in 2021

Read our case study

COMMUNICATION HIGHLIGHTS IN 2021

- Producing **Acknowledgement of Country** guidelines
- Publishing 13 articles in Materials Australia magazine, reaching industry audiences
- Four FLEET ECRs meeting government and policymakers at STA's annual Science Meets Parliament (see case study)
- Running media and presentations training for members, in collaboration with ARC Centres for Mathematical and Statistical Frontiers (ACEMS) and Fragment-Based Design (CFBD)
- Over 100,000 reached on external site Phys.org
- FLEET Director Prof Michael Fuhrer talking to Cosmos magazine about semiconductor manufacture and the end of Moore's Law .
- Jared Cole and Kris Helmerson's appearance in the **National Science Quiz**.

LEGACY

FLEET WILL:

- Promote public science awareness
- Improve public understanding of quantum science, electronics and sustainable computing
- Establish strong, lasting links between Australian and international science communities
- Develop the transferable (communication) skills of Australia's next generation of science leaders
- Improve public perception of diversity in science

INTERNAL COMMUNICATION

FLEET's internal communications function to:

- Foster Centre cohesiveness, both between participating nodes and between different research areas
- Improve understanding (e.g. between two quite diverse research fields: quantum information theory and nanodevice fabrication)
- Encourage collaborations between nodes and across research areas
- Ensure members know they are supported by the Centre
- Disseminate important information to members in a timely fashion
- Support other Centre strategic priorities, for example, in development, outreach, and equity (e.g. see FLEET Acknowledgement of Country).

FLEET's internal communications playbook is shared with members on the Centre intranet, along with annual reports, communications FAQ (process for getting studies published) and communications contacts at participating nodes.

In addition to the intranet, annual reports and the regular newsletter, all new members receive welcome emails outlining necessary Centre functions, logins and tools, and all-Centre meetings are used to keep members up to date with strategic goals, Centre processes and support mechanisms.

> FLEET introduced a number of new communications initiatives in 2020 as Covid and the lockdown took hold, and each of these proved useful at different times.

FLEET MEMBER SURVEY RESPONSE

> I think FLEET has narrowed the gap between the operations team and researchers. There is a 'personal' touch with FLEET's internal communication – it almost feels like home/family.

FLEET MEMBER SURVEY RESPONSE

> Being part of national research centre during a pandemic has been an interesting experience, as it pushed us to adopt new communication tools and new ways of connecting. Overall, I think 2021 saw a growing awareness of what worked and what didn't work. Personally, I found the new norm of "long-distance relationships" opened up some interesting possibilities for collaboration. That being said, "Zoom-fatigue" was a growing issue that members identified, and I can empathise so I am very eagerly looking forward to our face-to-face and hybrid meetings in 2022.

DR DAVID CORTIE
FLEET Communications Chair

COMMUNICATIONS SELF-SUFFICIENCY

While our members are in a Centre of Excellence, they have access to a communications coordinator who can help them share their research. But this will probably not be the case for most of a scientist's career. Therefore individuals should develop sufficient skills in communicating their research that they can do this themselves, without a full-time comms professional to help.

At FLEET, we are striving to develop the communications skills of our members, giving members the skills to share their research through several channels, including effectively leveraging university communications teams, online scientific platforms, and social media. An impressive 70% of FLEET members follow and engage with Centre social media accounts.

Progress towards this in 2021 includes:

- Building skills: sourcing and delivering communications training
- Supporting members in the recording of 'explainer' videos
- Finding opportunities and encouraging members to write non-peer reviewed articles – 25 articles in 2021
- Encouraging and supporting members sharing their science on social media
- Supporting members presenting their research in a public forum (see Outreach)
- Encouraging and supporting ECR and student members participating in Three-Minute Thesis, FameLab, Visualise Your Thesis, Science in the Pub, and similar.

Also see Honing members' communications skills.

We encourage members to take advantage of having a dedicated comms person now, at FLEET, to learn all the skills, to become 'self sufficient' in publicising their science. This means that in the future, they will be prepared for not having access to a dedicated comms person.

ERROL HUNT
FLEET Senior Communications Coordinator

CASE STUDY

Honing members' communications skills: Media and presentations training

Read our case study

CASE STUDY

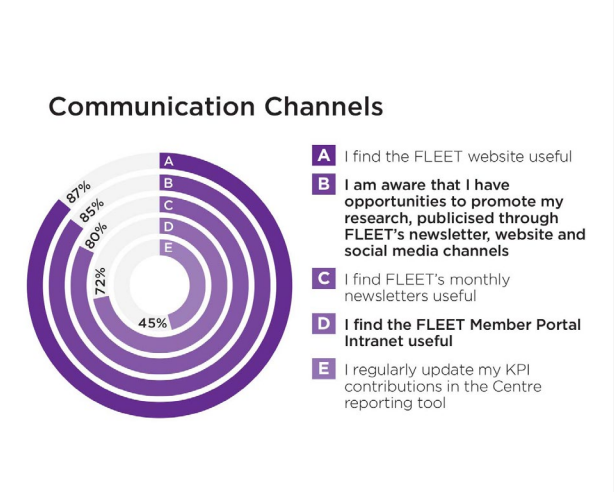
Engaging with policymakers: Science Meets Parliament

Read our case study

FLEET NEWS

The Centre's monthly newsletter reaches all 230 members and partners, with an edited version going to 220 external affiliates, followers and stakeholders. The newsletter achieves an open rate of approximately 50% among members, with 79% of members saying they find it useful.

As well as two or three highlight research stories each month, the newsletter shares wider FLEET news, including upcoming events, equity and training initiatives, Centre members' achievements, promotions and awards, and alum spotlights (see FLEET alumni). A regular feature congratulates ECRs as first and second authors that month.



IMPACT

FLEET's NZ partner organisation the MacDiarmid Institute reached out to FLEET Chief Investigator partner Prof Kourosh Kalantar-zadeh after reading about a 2020 study, leading to an NZ–Australia collaboration on surface-patterns, published in Nature.

> Frequent newsletters are nicely put together and update members with what's going on in FLEET and Centre's research achievements.
>
> **FLEET MEMBER SURVEY RESPONSE**

FLEET RESEARCH BLOG

FLEET's research blogs are the 'meat' in the communication sandwich, driving multiple communications channels (website, newsletter, social media, website, annual report), both external and internal.

FLEET's blog forms an extremely effective channel:

- Promoting members' research
- Celebrating members' achievements
- Highlighting Centre engagement with partners and the wider community.

FLEET puts significant effort into web-based blog posts that share Centre research news, along with outreach, training, equity and other news. The research blog targets both internal and external audiences.

The fresh, regularly-updated content from FLEET's research blog provides the content that keeps FLEET's social media fresh, providing compelling content for 3200 followers on Twitter, Facebook and LinkedIn.

Short descriptions linking to blog posts in the Centre's monthly newsletter also provide broad news to members, affiliates and stakeholders.

The same content, pushed out to online science platforms, supports the Centre's online media mentions and drives researchers' Altmetric rankings. FLEET papers given this coverage have consistently ranked in Altmetric's top 5% of papers tracked.

Reach on external sites significantly exceeds views on FLEET's own website. For example, on Phys.org alone, FLEET stories reached over 100,000 readers. Presence on these sites also means ongoing accessibility/publicity for the work done by our people long after the tenure of FLEET, even without the assistance of the planned FLEET legacy website archive.

FLEET members are highly convinced of the value of this coverage, with surveying indicating that 85% of members are aware FLEET can publicise their research, and over 90% of research blogs now suggested by the researchers, rather than prompted by the coordinator.

Most articles are aimed at a 'physics aware' audience, with the first section of the article aimed at a 'science aware' but non-physics audience. Thus, the maximum number of people will get some understanding from the start of the article, with more detail for increasingly-expert readers later on. This allows articles to be published on as wide as possible a range of outlets.

For internal purposes, articles aim to improve understanding of other work around the Centre. The aim is, for example, that an Enabling technology B (nanofabrication) PhD student will be able to read and understand an article about Research theme 3 (non-equilibrium physics), and vice versa. This internal sharing of research blogs is accomplished via newsletter and social media.

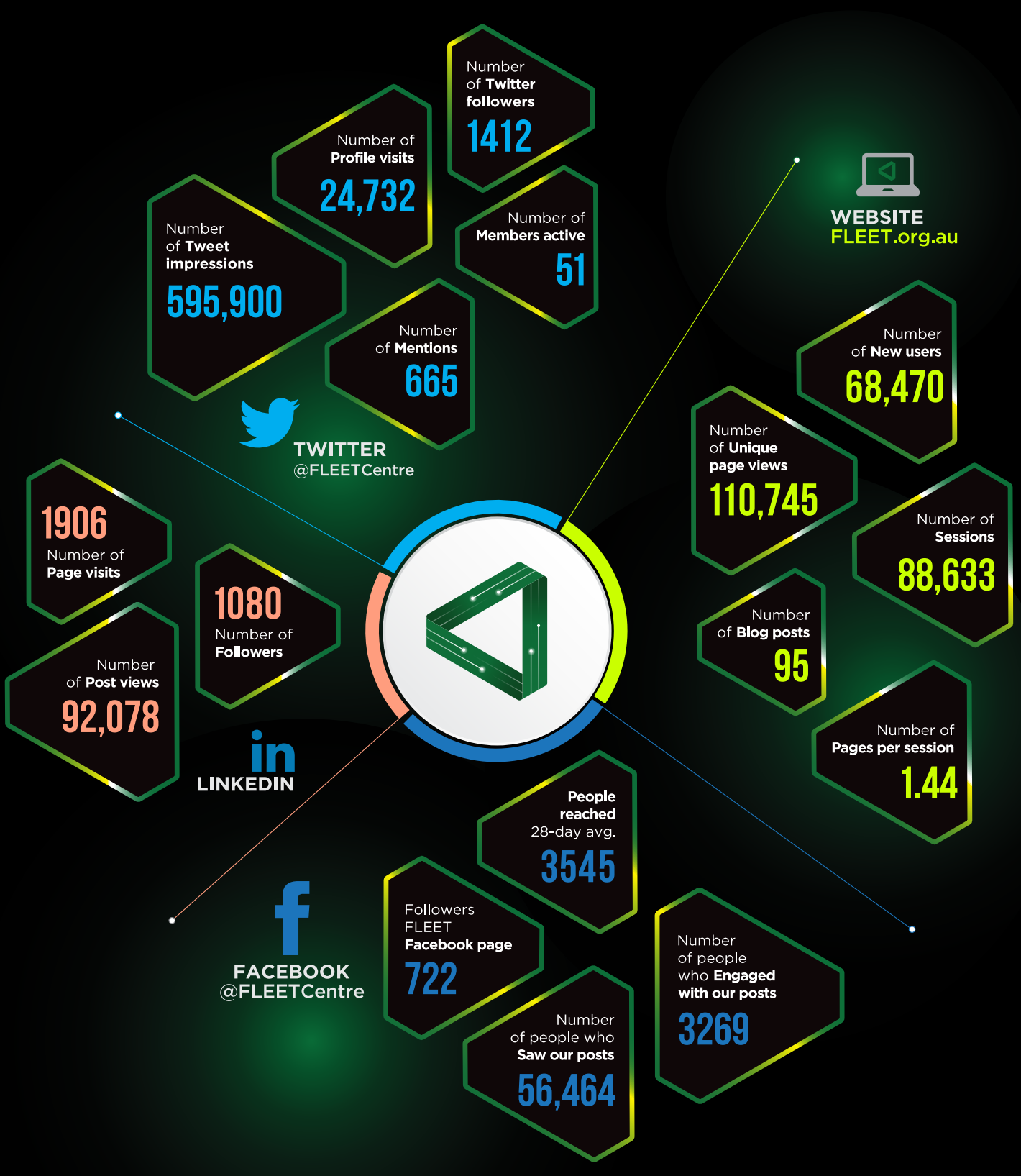
FLEET uses mainstream media, university and partner communication teams, and online science platforms to communicate Centre research results to the public as well as to science peers. The Centre has twice voluntarily increased the 'media mentions' target, after exceeding the original goal by a factor of more than 10, and in 2021 has once again exceeded this KPI.

In 2020–21, with many members concentrating on write-up, the Centre put extra effort into sharing the news of this research. In total, 30 FLEET stories had full press-release distribution (compared with 10–13 in pre-Covid years), with these driving the bulk of the Centre's 459 media mentions in 2021, and improving members' visibility to potential global collaborators and industry.

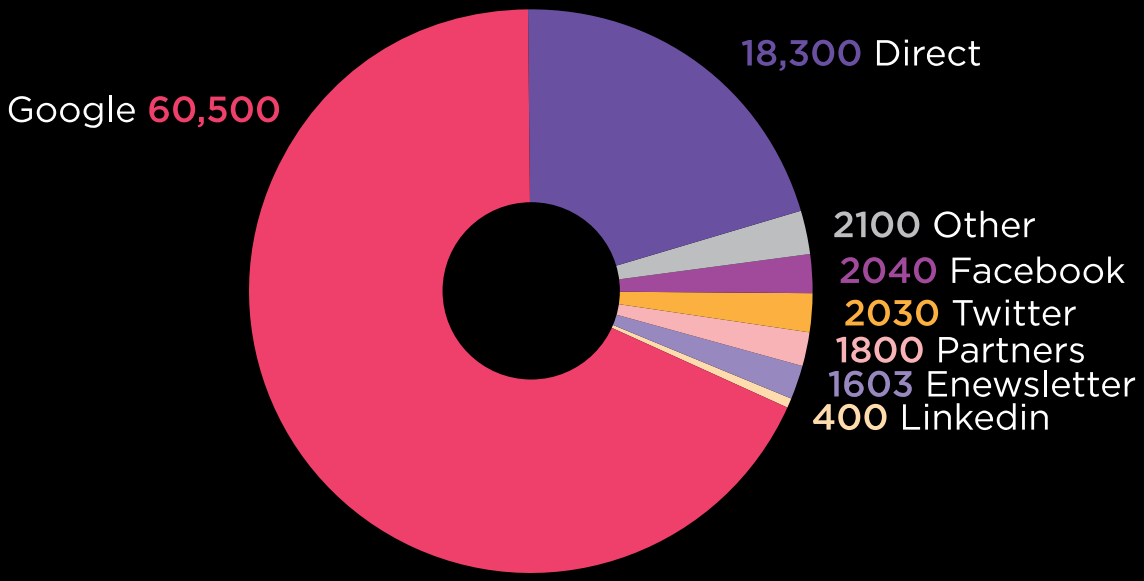
Also see FLEET's **online and social-media** news functions.

> FLEET engages with the scientific research community through research stories published on key online science platforms and stakeholders' newsletters.
>
> **FLEET COMMUNICATION STRATEGY**

FLEET online



FLEET online



Also see FLEET's new Ask the Physicists page

A silver lining of the Covid pandemic travel restrictions was to force quick expansion of virtual meetings and other online tools. I expect we will use some of these online tools long into the future, as they've helped us meet more frequently, with less of an environmental footprint, and potentially improve our ability to directly interact with a broader cross-section of the public, as well as other scientists.

DR DAVID CORTIE
FLEET Communications Committee Chair

Engaging public conversations at Melbourne Knowledge Week

Flying the flag for future computing

CASE STUDY

Melbourne Knowledge Week (April/May 2021) was an opportunity for FLEET to engage with over 350 members of the public about the exciting future of computing, and the vital role of energy-efficient electronics in that future.

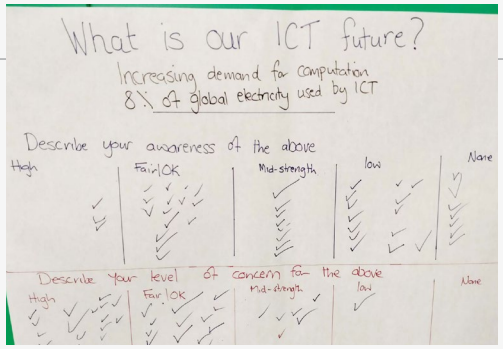
FLEET's 'sustainable computing' booth at the festival hub included hands-on science demonstrations linked to materials used in FLEET research, such as gallium, bismuth and ferrofluids.

The exercise also gave 13 Centre members from FLEET's three Melbourne universities the opportunity to gain valuable experience in public science outreach, speaking to a diverse audience.

> This type of public outreach helps me become a better communicator, both with the public and with people from other scientific disciplines.
>
> **PATJAREE AUKARASEREENONT (RMIT)**
> *PhD student*

Many researchers also find that the value of such outreach experiences extends beyond developing specific skills or achieving KPI outreach hours – it reminds them of their own passion for science:

> Seeing other people's interest in our work helps remind me of why I'm doing this research and keeps my passion in science alive.
>
> **FLEET VOLUNTEER, MELBOURNE KNOWLEDGE WEEK**



FLEET's presentations had a positive effect on visitors' appreciation and awareness of physics.

One of FLEET's outreach objectives is to get people to think critically about the role and implications of FLEET's research. FLEET presenters at the Melbourne Knowledge Week booth discussed with public visitors what value they put on computational power. For example, driverless cars, the Internet of Things, or artificial intelligence for disease diagnosis and treatment.

Discussions explored visitors' perception of the energy demands of computing, and what value they would place on FLEET's search for low-energy electronics, aimed at allowing computing to continue to grow.

Visiting members of the public became aware for the first time of the increasing demand for computation and the associated energy requirements: "I'd never thought of the computation–electricity demand problem and how closely related the issue is with my technology needs.

"It is definitely an eye opener. Visitors who worked in computing were particularly interested. For example, a virtual-reality visual artist mentioned he'd never considered the consequences of his own work's high computational demand, realising with some concern that his environmental footprint was 'massive'. And a data-centre worker said she'd been prompted to realise that her role in encouraging more users onto 'the cloud' had social and environmental implications.

"What does a scientist look like?" FLEET's Dr Iolanda Di Bernardo (Monash) beside schoolkid's representations

Conversations were in-depth, with most conversations being around 10 minutes long. Visiting public were surveyed before and after the conversations, to gauge their awareness (low) and concern (high) about ICT energy use, and their appreciation of physics after speaking to FLEET.

Such events also help humanise scientists, in particular, exposing schoolkids to working scientists outside the 'pale, male and stale' stereotype whose laws they might learn in class.

Research shows that challenging kids' early gender biases towards professions can influence their future career choices.

"

Kids can't be what they can't see, so we are trying to challenge gender stereotypes in children by demonstrating to them that a scientist can look feminine too.

DR IOLANDA DI BERNARDO (MONASH)
FLEET Research Fellow

More at FLEET.org.au/MKW2021

Igniting a spark for learning in primary school students

Discovering the learning power of the periodic table

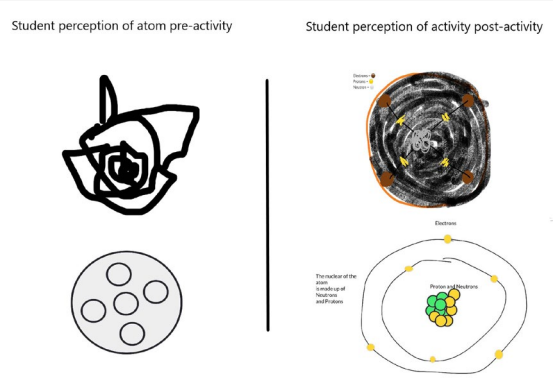
CASE STUDY

A FLEET visit building better understanding of electricity and atomic structure uncovered several lessons in the role of hands-on investigation in building student understanding

A cooperative FLEET project with a Melbourne primary school taught students to think about atoms, electricity, conductors and insulators, with an 85-student Year 6 pilot workshop testing success in building understanding of atomic structure and electricity, and promoting critical thinking about electricity, society's application of it, and more broadly the value of research.

Built-in evaluation processes indicated those objectives were met, but also revealed that students' hands-on investigations, including examining a periodic table, building a model atom, and building different electrical circuits, were crucial to that improved understanding.

Students were asked to consider how electricity has changed the world and imagine how they would feel if we did not have electricity: "Without electricity, it would be hard to communicate to family that don't live near you." "There would be no toasters no baths no lights no iPads or PlayStation." Coping with Covid without electricity would be bad: "We would feel sad and lonely in lockdown without power."



Students were asked to draw their ideas about the structure of an atom.

Introducing the atom and the power of the periodic table

Students were asked to draw an atom, both before and after an in-class discussion and hands-on exercise about atomic structure. Students' initial ideas about atoms (often an indistinct blob with no distinct nucleus) were significantly improved by using the periodic table to select an atom to construct a physical model.

The model atom exercise not only allowed conceptualisation of atomic structure. It also provoked the realisation that atoms come with different sizes and properties to make up all the different elements of the universe.

There was a realisation that the type of atoms determines what they can feel, see, touch or smell: students commented they'd learned that there are different types of atoms, and that "the different atoms are determined by the number of protons, neutrons and electrons".

"The power of the periodic table as a learning tool in this context was unexpected!" says FLEET outreach coordinator Jason Major.

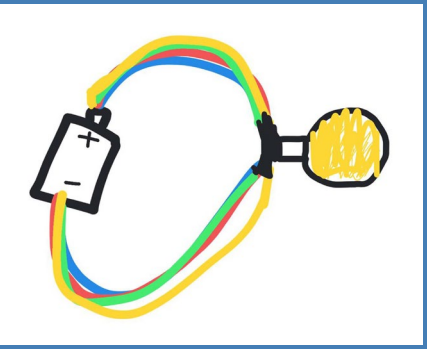
Building better circuits

After in-depth discussion, and hands-on circuit construction, nearly all students were able to describe a correct circuit. Most understood which way electrons flowed through a circuit, and the charged particles' role in the flow of charge and electricity ("Electrons only produce electricity when moving") and practical considerations were also learned ("When you power something up, the alligator clips get hot").

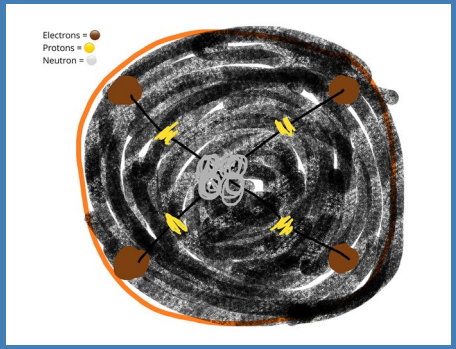
Considering the value of research

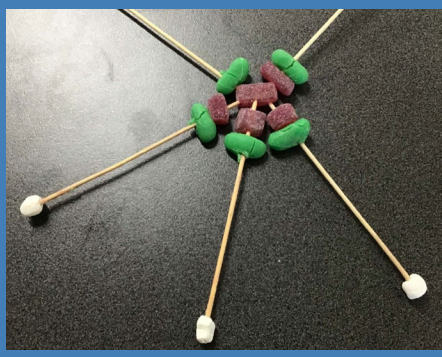
As an example to get students thinking about societal value of science, the class talked about FLEET's research mission to develop low-energy electronics, within the context of the computational and energy requirement of digital technologies.

Students thought critically about the value of such research, with a high focus on societal challenges such as sustainability, climate change and making the world better: "We would waste less electricity" and "It would help reduce climate change". They became aware of the value of reducing energy consumption and the value of having energy-efficient technologies to help achieve that goal.

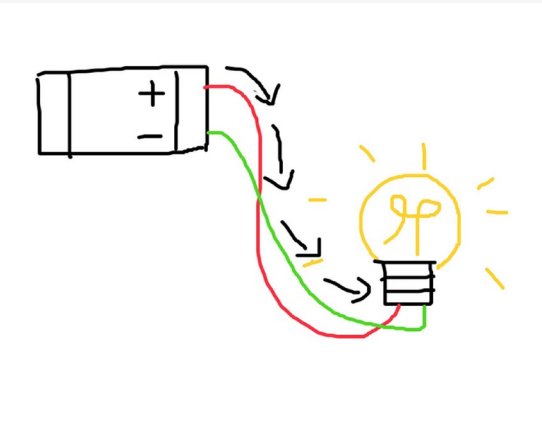


Base case understanding: Less than half the students managed a correct circuit on their first attempt, with multiple wires being a common misunderstanding.

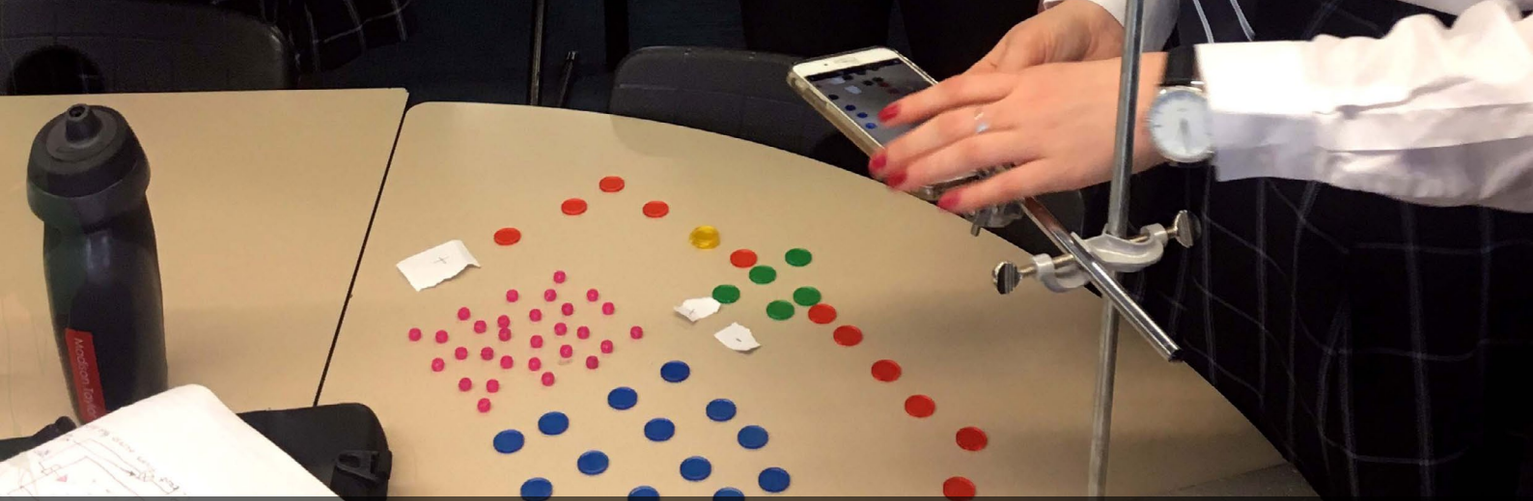




Students' understanding of atomic structure improved markedly on initial concepts (left/top), after being coached to construct a 'lolly model' (right/bottom)



More at FLEET.org.au/spark2021



Student surveys confirm benefits of FLEET Future electronics unit

Sealing the deal for physics

CASE STUDY

Surveying and interviews confirm success of elective unit in encouraging girls/other students in physics.

Over the last three years FLEET has helped put around 90 Year-10 students through a 'Future electronics' unit, in partnership with John Monash Science School (JMSS).

As well as covering semiconductors, Moore's Law and computing, the course introduces quantum physics at an intuitive level (with minimal maths) and expands on this fundamental understanding to explain complex, useful quantum states such as superfluids and topological materials.

Surveys confirm that students have enjoyed and been engaged in the topics covered. And that, despite many students finding some topics difficult, they still enjoyed and were interested in the unit.

In addition to students finding the unit interesting and enjoyable, the unit revealed to students a breadth and depth to the discipline of physics that they'd previously been unaware of. Students enjoyed researchers' raw, unfiltered stories about their research and its application to real-world problems.

The FLEET–JMSS unit affected students' consideration of physics as a subject in the future. Many students who had not considered physics said the unit may have changed their minds. For the students already planning to do physics, the unit helped reinforce that decision: "I had been tossing up doing physics in VCE over the last couple of weeks and this is kind of sealing the deal for me."

FLEET presenters helped to develop and deliver the courses, exposing students to a much more diverse cast of physicists than the 'pale, stale and male' 19th-century gentlemen whose names and biographies are traditionally taught in physics classes.

Interviews with female students confirmed that the presence of female presenters enabled the students to see a place for themselves in physics.

> At my old school, subjects like psychology, physics, biology were more male-dominated subjects, and [it felt like] females shouldn't be in those subjects. Seeing the female speakers from FLEET inspired me to consider physics, just because I could see now there's a place for females in this field.
>
> **STUDENT, JMSS**

> Our teachers at JMSS have a lot of expertise in these areas already, but having someone who is currently doing research on this topic gives a deeper insight. It feels like what we're learning is unfiltered.
>
> **STUDENT, JMSS**

Surveying and interviews confirm that the involvement of FLEET researchers played a crucial role in student enjoyment and engagement, making physics real, palpable and inclusive. This engagement enabled students to envision multiple opportunities in physics, opening doors to consider new, varied career paths.

FLEET presenters highlighted to students the breadth of opportunity within physics, and discussion of real-world applications helped students realise the value of physics. "There are many components and jobs which compose this field and it really opened my eyes to the many possible job careers." "Meeting the researchers showed me a career that I could pursue, and after doing this topic I gained a lot of interest in it."

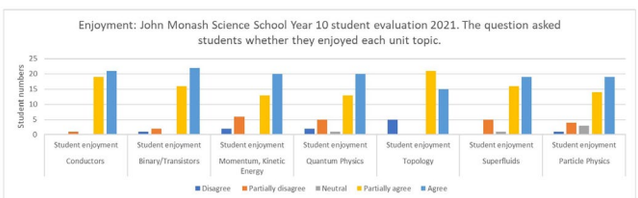
Within the overriding structure of putting FLEET science into context, content taught covered the spectrum from fundamental atomic and quantum physics to applied computing and technology.

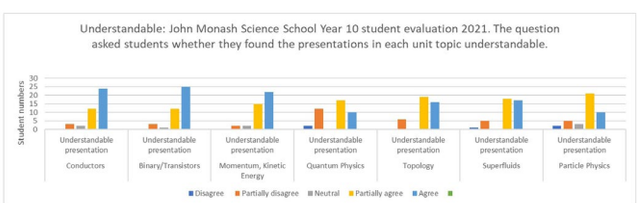
This diversity of topics meant that most students were able to find at least a few topics they were really interested in: "It was interesting to cover so many topics not normally talked about in normal classes. I liked the variety of topics we studied, as we learned a small amount of interesting information about each topic."

The unifying connection of seeking low-energy electronics illustrated for students that fundamental research could work towards a real-world application: "Even though FLEET's research is quite complicated and the field is pretty new, concepts like cold atoms that might seem unrelated to electronics actually play a key role in developing low-energy technology in the future."

The Future electronics unit will be repeated in 2022. In the next 12 months, more female students will be interviewed to gain a clearer picture of their response.

The FLEET–JMSS unit represents the first time Australian school students have been taught about superfluids and topological materials. With the current focus on Australia's future quantum workforce, the example of applying quantum science to real-world issues is particularly useful. As is the introduction of semiconductor science to school students.



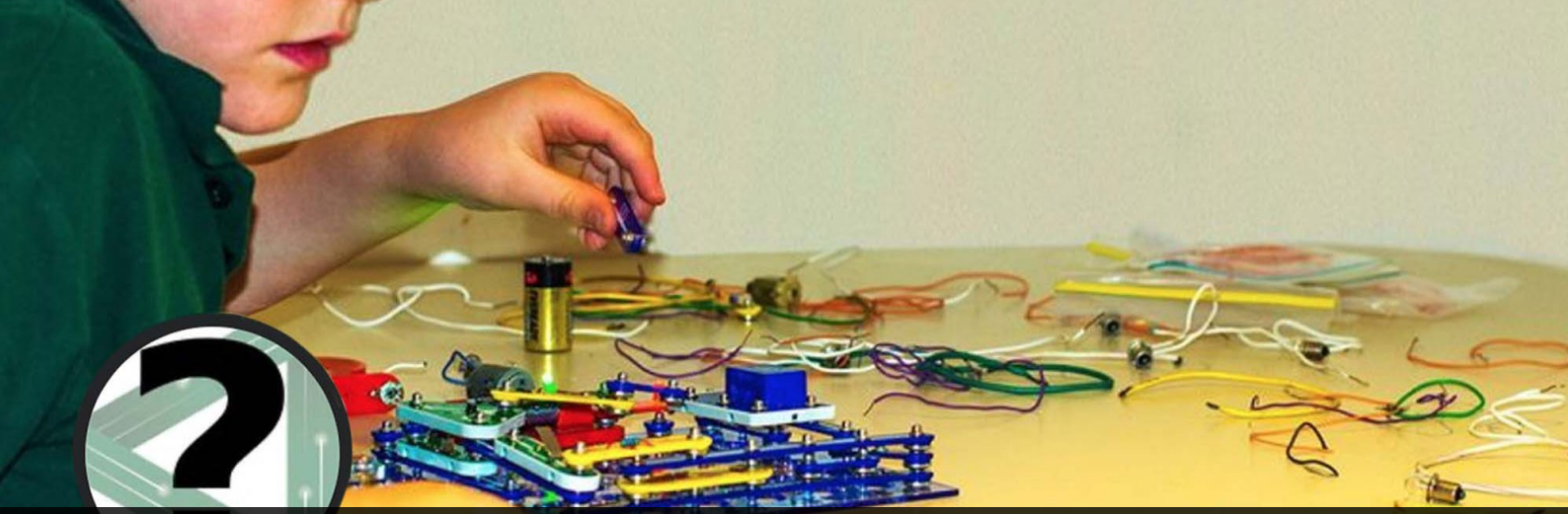


The inclusion of multiple different topics in the unit, united by themes of semiconductors and the search for low-energy electronics, meant that almost all students were able to find at least one topic that really fired their interest.

IMPACT

Surveying found 80–100% of students found the topics interesting, and 80–97% found the topics enjoyable.

More at FLEET.org.au/JMSS2021



Engaging Q&A: FLEET's 'Ask the physicists' page

Leveraging social media for science outreach

CASE STUDY

Are hoverboards real? What's lightning? Can we time travel? Can I predict where a rainbow will form? What is electricity, and who were the first electricians?

FLEET's new 'Ask the physicists' Facebook page, introduced in 2021, encourages schoolkids, parents and others to ask their hardest, most-baffling questions, which FLEET members find an answer for.

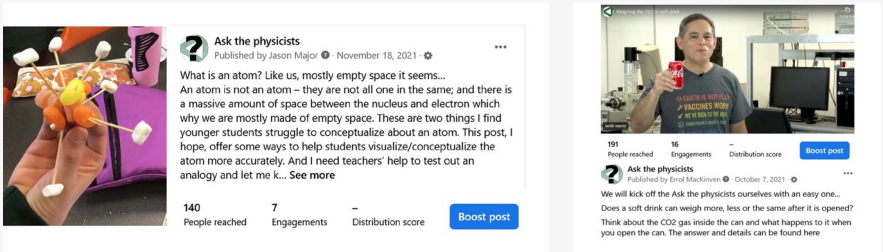
FLEET members, affiliates and partners are enlisted to help spread the page, or to help answer questions, developing valuable science-communication skills.

The new platform enlists the pervasive power of social media to counteract the school lockdowns, encouraging primary and secondary teachers and students to ask the most curious or baffling scientific questions.

FLEET members research and compose comprehensive, clear answers to the questions, providing members with another opportunity to practice their scientific-communications and engagement skills. FLEET also posts questions and answers, based on topical science news and other engaging physical sciences content.

The new page is also a useful platform to alert teachers to FLEET outreach and schools' resources and programs, promoting the availability of FLEET members to visit classrooms, online engagement, and home-science resources.

The initial focus has been on Victorian primary teacher Facebook groups, and it will be expanded to Australia-wide teacher groups, primary and secondary, in 2022.



Does a soft drink can weigh more, less or the same after it is opened? What is an atom? FLEET members compose comprehensive, clear answers to public questions, as well as repurposing existing science-communications content (in this case, from the National Science Quiz and a primary school project) to maximise impact.

Outreach legacy: Accepting the baton for National Science Quiz

Providing tha public with a view of 'scientists doing science'

CASE STUDY

For six years the annual National Science Quiz has provided the public with a live, entertaining demonstration of 'how science works' to solve problems, under the aegis of initiating and coordinating institution, the ARC Centre for Mathematical and Statistical Frontiers (ACEMS).

From 2022 onwards, FLEET will work with a team of other ARC centres to ensure the annual public event endures beyond the tenure of its host organisations.

The National Science Quiz is a celebration of science, the key feature of which has always been a panel of scientists and science communicators who apply equal doses of humour and scientific reasoning to answer a series of thought-provoking questions across multiple branches of science.

Panel host each year has been comedian, ABC TV and radio presenter Charlie Pickering.

The principle of 'showing your working' has always applied, so that the audience can follow the thought processes of panellists as they deduce the correct answer.

The Quiz is designed to engage the public and provide a view of 'scientists doing science', sparking an interest in science in the younger generation in particular, to help them consider future study or careers in science.

In 2021 there were a large number of families amongst the 1200 participants in the live, online competition, pitting their knowledge and skills against other teams to compete for prizes. (Three times as many again viewed the event later on YouTube). The initial focus has been on Victorian primary teacher Facebook groups, and it will be expanded to Australia-wide teacher groups, primary and secondary, in 2022.

Prof Kris Helmerson (Monash) recorded a series of videos explaining science questions posed to panelists and audience.

PASSING THE BATON

In 2021 FLEET was one of the team of co-hosts coordinated by Centre for Mathematical and Statistical Frontiers, along with The ARC Centres for Exciton Science, Gravitational Wave Discovery (OzGrav), Advanced Molecular Imaging, and Synthetic Biology, with Inspiring Australia.

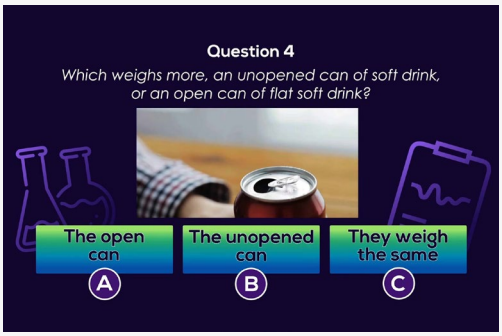
The long-term goal is that the Quiz becomes an ongoing, annual feature event of the National Science Week program – beyond the terms of the science organisations that host it.

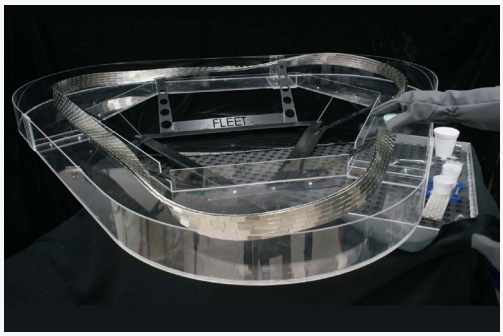
“Over five years, the Quiz has built up a loyal following, which it would be a shame to lose,” says FLEET outreach coordinator Dr Jason Major.

From 2022 onwards, with the Centre for Mathematical and Statistical Frontiers having finished its funding term, the baton has been passed from ACEMS to FLEET. However this is just the first step in the process to ensure the longevity of this valuable asset.

As initial Chair of a new NSQ Steering Committee, FLEET takes on the task of assembling a new, diverse team of partners and sponsor organisations. FLEET will establish a culture of rolling responsibility, with each centre taking on responsibility to Chair the committee and host the Quiz each year.

As Centres mature through their lifecycle (seven years for an ARC Centre of Excellence), this approach should provide adequate opportunity for Centres to develop their involvement in the National Science Quiz, take the lead and then pass on the baton to other Centres.





National Science Quiz audience participation combines multiple-choice questions and engaging explanatory videos

The current National Science Quiz committee members are outreach and communications officers at FLEET, the ARC Centres for Exciton Science and Plant Success in Nature and Agriculture, and the MATRIX Institute at the University of Melbourne’s School of Mathematics and Statistics.

As well as ensuring adequate funding, there is a usefully diverse science focus amongst participating centres, including physics, chemistry, agriculture and maths. In addition, individuals on the committee bring skills in outreach, communication, publicity, live events and TV.

This is a new model for ongoing outreach events amongst ARC Centres. It means the great work done by ACEMS over the last six years will continue – and we will ensure it continues beyond FLEET’s tenure too. Essentially, we’re applying the same principles of legacy and sustainability to this valuable science-outreach asset as Centres do to research translation!

DR JASON MAJOR
FLEET Senior Outreach Coordinator

Maintaining cohesion: Centre meetings in 2021

Online and physical Centre meetings maintain connections

CASE STUDY

Balancing the need to maintain Centre cohesion with Covid-restrictions and 'zoom fatigue', FLEET has used multiple channels, including physical and online meetings.

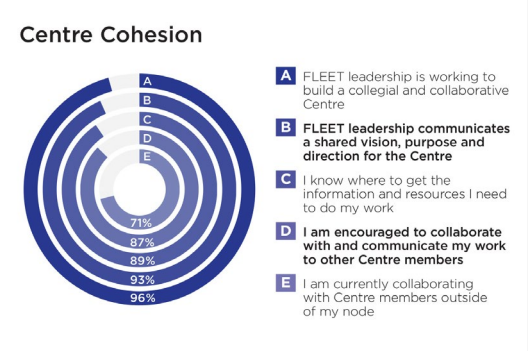
Centre cohesion has been a particular priority in 2020–21 for FLEET, as for many other organisations.

In addition to 'fluid' platforms such as Slack, regular weekly events emails, the Centre newsletter, and journal clubs, FLEET ran two major all-Centre meetings in 2021, managing hybrid, physical and online formats as safety and Covid restrictions allowed.

FLEET's midyear strategy meeting was a hybrid event, with Melbourne-based members able to attend in person and interstate members attending online. The meeting reviewed and renewed FLEET's research milestones and strategic plan. Governance areas (equity, research translation, outreach, communication and training) were also reviewed.

FLEET's cut-back end-of-year meeting (FLEET2021) included relatively-brief scientific talks covering the broad research areas across the Centre, with all the research 'detail' covered in ECRs' posters.

FLEET has continued experimentation with new online virtual-meeting platforms, trialling Kumospace and MeetAnyway to allow organic discussions and poster sessions. At FLEET2021 the MeetAnyway platform allowed 79 poster presenters to share their research detail, interacting with online poster visitors.



FLEET2021 saw 136 attendees engaging over the three days, culminating with an awards presentation and physical catch-ups.

82% of participants said they have been able to maintain a strong connection with FLEET through Covid, in the Centre's 2021 Centre-wide survey.

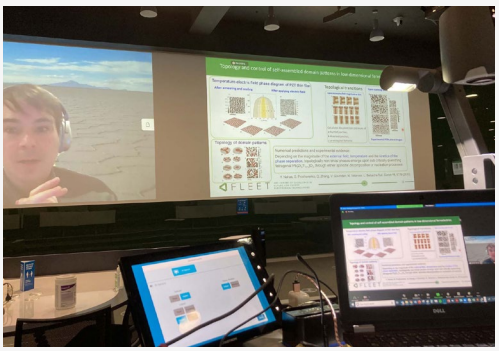
> I liked the FLEET2021 access dashboard, easy to access all the information and events, really well done.
>
> **FLEET2021 MEMBER FEEDBACK**

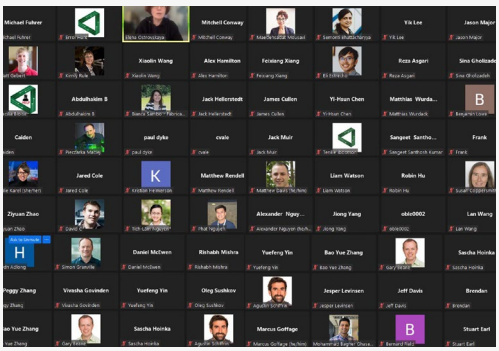
Physical catch-ups were possible only in Sydney and Melbourne, but these allowed members from the four nodes in those centres a welcome chance to reconnect face-to-face with some Centre colleagues they hadn't seen since 2019.

Talks were minimised in the end-of-year meeting in recognition of 'Zoom fatigue', with people under significant stress in and outside of work finding it increasingly tiring to engage online.

> The casual schedule was good. End of year is pretty hectic, so it is nice to have something which isn't trying to gobble all our time via Zoom.
>
> It was valuable to get an overview of what's happening in different research themes and groups of FLEET.
>
> **FLEET2021 MEMBER FEEDBACK**

FLEET will hold a hybrid meeting in Wollongong in mid-2022, bringing together the entire Centre for the first time since the start of the pandemic, while also catering for international partners who may not be able to travel and any members reluctant to attend for health reasons.





> I got to talk to a few poster presenters from outside my field. The research theme updates were very good at giving me an overview of FLEET's activities across all the research groups.
>
> **FLEET2021 MEMBER FEEDBACK**

Honing members' communications skills: Media and presentations training

Developing transferrable skills in media, presentation and communications

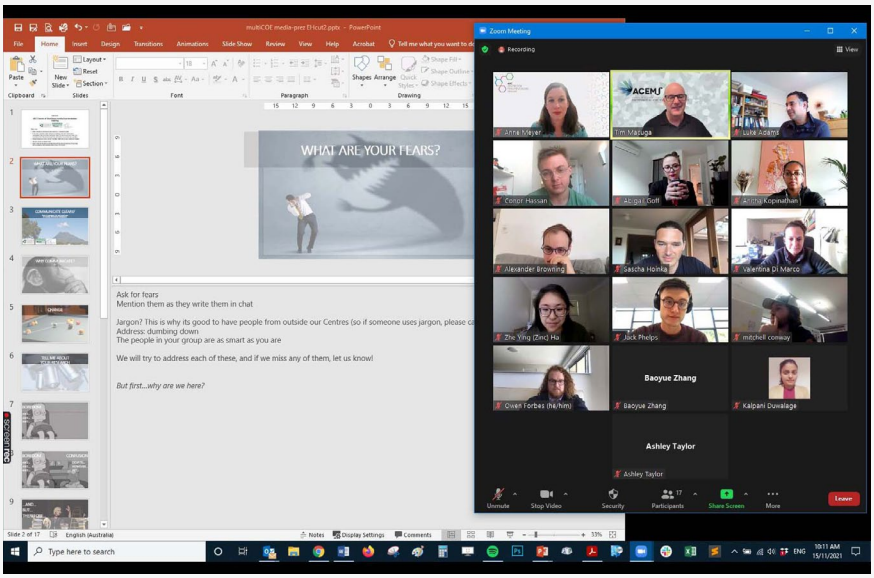
CASE STUDY

FLEET joined with three other ARC Centres to run a one-day media communications workshop, facilitated by the Centres' communications professionals.

Participants in the workshop developed confidence for future interviews and learned how to get their message across with the media and the general public or in job interviews.

Communications fundamentals included how to build your narrative, how to control the interview, and how to deal with and master 'difficult' questions. There were hands-on group exercises with delegates from the other centres and mock interviews to practise their skills.

While the focus was on communicating with media, the same skills are also key for job interviews, outreach activities, speaking to the public, TV and radio interviews, fellowship applications, pitching ideas to companies, and delivering presentations.



Training was conducted via Zoom, allowing participation of researchers from all four Centres across NSW, Victoria, Queensland and WA.

Breakout rooms allowed plenty of time for small-group discussions and practice, which the following evaluation indicated was extremely valuable.

The workshop was a joint event between FLEET and the ARC Centres for Climate Extremes (CLEX), Mathematical and Statistical Frontiers (ACEMS) and Fragment-Based Design (CFBD). The participation of such a diverse group of researchers was extremely valuable in pitch practice, reinforcing the need to avoid 'in-house' jargon.

Presenters and content creators were the communications coordinators at the four Centres of Excellence, who brought decades of combined experience in media (print, TV) and communications.

> The training was well structured, and I came away with the key points. I'm glad that there was not an overload of information, and I have already started applying some of the things that I have learnt.
>
> **TRAINING ATTENDEE**

EDUCATION

FLEET is developing future Australian science leaders, and preparing them for future success.

EDUCATION AND TRAINING

3
RESEARCH WORKSHOPS AND CONFERENCES ORGANISED

12
RESEARCH AND PROFESSIONAL DEVELOPMENT WORKSHOPS

1254
TOTAL CUMULATIVE NUMBER OF MEMBERS ATTENDING TRAINING WORKSHOPS

506
TOTAL CUMULATIVE NUMBER OF NON-MEMBERS ATTENDING TRAINING WORKSHOPS

4
MENTORING PROGRAMS

47
MENTEES

52
MENTORS

4.9
MENTORING QUALITY SCORE OUT OF 5 STARS

Building future science leaders

FLEET is working to develop Australia's next generation of science leaders.

All FLEET's students and young researchers receive excellent supervision, are offered world-class training and other opportunities for professional development, and are supported in navigating diverse future career pathways.

The Centre currently supports 56 higher degree by research (HDR) students and 49 postdoctoral researchers, and another dozen research affiliates work on FLEET projects and are invited to Centre training, workshops and events.

PhD students are given the opportunity to have an associated supervisor from one of the other FLEET nodes, which helps with cross pollination of ideas and development of collaborative projects.

CASE STUDY

Improving transferable skills: Idea Factory 2021

Read our case study

LEGACY

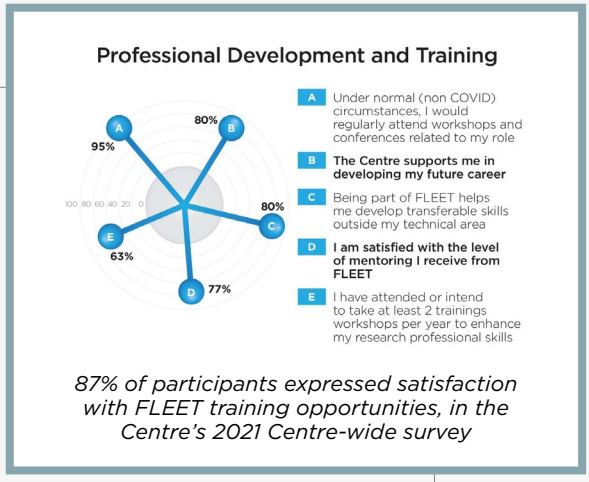
FLEET WILL:

- Develop Australia's next generation of science leaders
- Train researchers in the electronics of tomorrow

STRATEGIC PRIORITIES

- Develop world-class training and mentoring programs
- Establish Centre succession planning (see **strategic plan** p23)
- Facilitate opportunities for research collaboration
- Establish a collaborative culture within the Centre
- Facilitate opportunities for career development in industry
- Identify opportunities for members to be recognised

FLEET training programs are valued by Centre members. This year's Centre-wide survey (found that under normal circumstances FLEET members would regularly attend workshops and conferences related to their roles, that they know where to access information about opportunities, and that they believe they can develop new skills within and outside their technical areas.



87% of participants expressed satisfaction with FLEET training opportunities, in the Centre's 2021 Centre-wide survey

Despite the impact of Covid, members feel strongly that the Centre supports them in developing their future career (80%), developing new skills in their technical area (80%) and developing transferable skills outside their technical area (80%). Almost 90% of participants found the 2021 Idea Factory valuable.

2021 HIGHLIGHTS

- Implementing new mentoring platform Mentorloop
- Running quality technical tutorials, presented by both FLEET ECRs and external experts
- Developing transferrable career skills: **Idea Factory**.

IN 2022 FLEET WILL...

In 2022 FLEET will conduct strategic evaluation to better understand the impact and effectiveness of the Centre's training, identifying areas for future improvement. The Education Committee, working with the Communications Committee, will also investigate new digital tools to enable more-effective online training.

FLEET will provide targeted training in research translation, coordinated via the **new translation manager** translate).

CASE STUDY

Young researchers driving FLEET's training program

Read our case study

FLEET TRAINING PROGRAMS IN 2021

Training workshops were delivered on topics ranging from advanced physics to transferable skills such as career planning, writing, industry engagement and communication.

In 2021, Covid restrictions forced most training to be held online, but where possible FLEET used a hybrid delivery system. As a lasting improvement to the way we work, in 2020–21 FLEET has significantly widened access to training programs. This year, a total of 1254 FLEET members accessed Centre or external training, against a target of 150.

In 2021 the Centre held 12 workshops offering research and professional development opportunities for members, with many workshops also open to students and ECRs outside, or adjacent to, FLEET.

> FLEET offers opportunities for ECRs and PhD students to attend and participate in workshops that not only relate to their research but to enhancing their capabilities in other areas (leadership, etc.).
>
> **FLEET MEMBER SURVEY RESPONSE**

Training in 2021 included:

- Research tutorial Quantum Hall effect and chiral superconductors, conducted by Dr Stephan Rachel (University of Melbourne)
- Building leadership skills (Women and Leadership Australia)
- Venture capital-backed startups, with Antler's Laura Faulconer exploring the process of high-growth, deep-tech start-ups, including the investors backing them
- Taking charge of your career, run by Dr Charlotte Hurry (former FLEET EO)
- Media and presentations training for members, in collaboration with ARC Centres for Mathematical and Statistical Frontiers (ACEMS) and Fragment-Based Design (CFBD)
- Writing scientific research articles, run by A/Prof Patrick O'Connor (University of Adelaide)
- Applying for a Discovery Early Career Researcher Award (DECRA) panel discussion, with past and present DECRA fellows sharing personal experiences
- Effective personal and communication skills, run by Odyssey Training
- Ascend research impact and industry engagement
- Idea Factory.

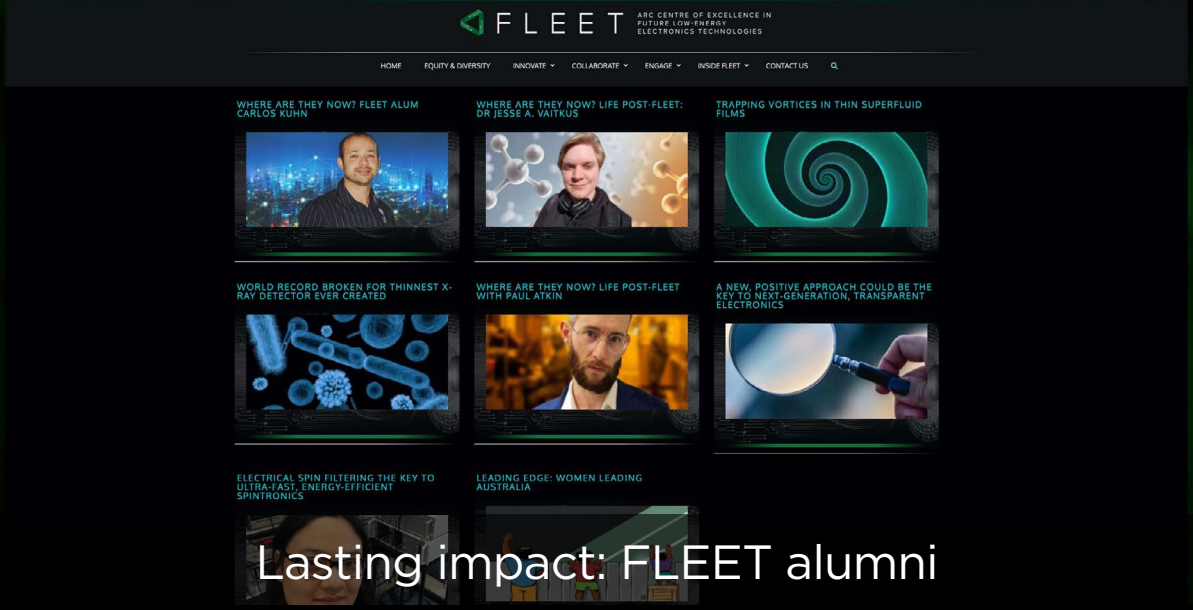
> The leadership workshops run by Dr Charlotte Hurry were a valuable resource and certainly have opened my eyes to other career opportunities and possibilities.
>
> **FLEET MEMBER SURVEY RESPONSE**

In 2021 the Centre began a series of talks aimed at strengthening members' knowledge of issues in industry, with the first three in the series covering research commercialisation, commercialising semiconductor science, and transitioning from academia to commercialisation (see Industry-engagement seminars).

A highlight in equity and diversity awareness training in 2021 was the panel 'What makes women strong in what they do?' organised by FLEET Research Fellow Dr Peggy Schoenherr and featuring five FLEET women sharing their personal experiences. FLEET also ran Active bystander training, facilitated by the Monash University Respectful Communities unit.

FLEET members also took the initiative to pursue their own FLEET-relevant training. For example, Python and grant writing workshops.

FLEET's ambitious science-outreach program, in which all members are asked to do 20 hours of outreach each year, also represents significant transferable-skills development. In the Centre's 2021 survey, 95% agreed that FLEET's outreach and communication activities provide opportunities to improve their own communication skills.



Lasting impact: FLEET alumni

Members who have already moved on to great new careers leverage skills developed at FLEET.

Ultimately it will be FLEET's alums as much as its research outputs that define the success of the Centre.

One of the most lasting and valuable legacies left by any Centre of Excellence is its people, and four years into the life of the Centre, FLEET is already seeing its alumni move on to great careers in diverse areas. We are extremely proud of our alumni, and for both personal and professional reasons, FLEET works hard to maintain contacts – sharing alums' stories with current members and keeping alums connected via Centre communications.

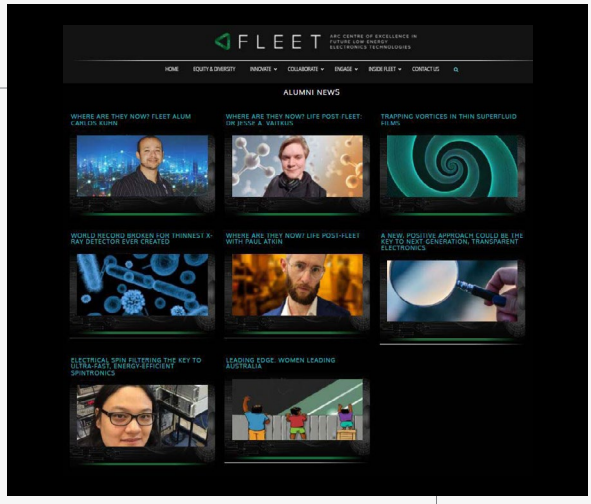
Four years in now, I've now seen students who started their studies in FLEET submit their theses and graduate, and postdocs land their first permanent positions. It's bitter-sweet to see FLEET members moving on, but I am glad we've made their experiences better. I hope they'll take a bit of FLEET with them when they leave, and make the place they go better as well.

PROF MICHAEL FUHRER
FLEET Director

Congratulations to the following FLEET members who submitted their PhDs in 2021:

Alexander Nguyen (Monash), Chutian Wang (Monash), Dhaneesh Kumar (Monash), Guangsai Yang (University of Wollongong), Haoran Mu (Monash), Muhammad Nadeem (UOW), Sultan Albarakati (RMIT), Tatek Lemma (Swinburne), Tinghe Yun (Monash), Tommy Bartolo (RMIT), Vivasha Govinden (UNSW), Wafa Afzal (UOW), Weiyao Zhao (Monash), Yonatan Ashlea-Alava (UNSW)

ALUMNI HIGHLIGHTS



Ex-FLEET members **Dr Dianne Ruka** (previously FLEET's outreach coordinator) and **Dr Charlotte Hurry** (executive officer) both moved on from FLEET to lead their own ARC Centres, with Dianne heading up the new ARC Training Centre for Cell and Tissue Engineering Technologies, and Charlotte leading the ARC Training Centre in Optimisation Technologies.

Dr Hareem Khan (previously with FLEET at RMIT) was recognised by the RMIT HDR Impact Award, recognising considerable impact outside the academia. Hareem is now continuing her investigations of synthesis and study of atomically-thin materials in electronic devices with CSIRO Energy.

FLEET alums have moved on to diverse new roles, from Australian and international commercial scientific entities to consulting, finance, government policy or publishing. Of those choosing to remain in academia for the present, many have moved overseas, securing postdocs, fellowships or lecturer roles in Belgium/Switzerland, Canada, China, France, Germany, Italy, Saudi Arabia, Singapore, Spain and the US.

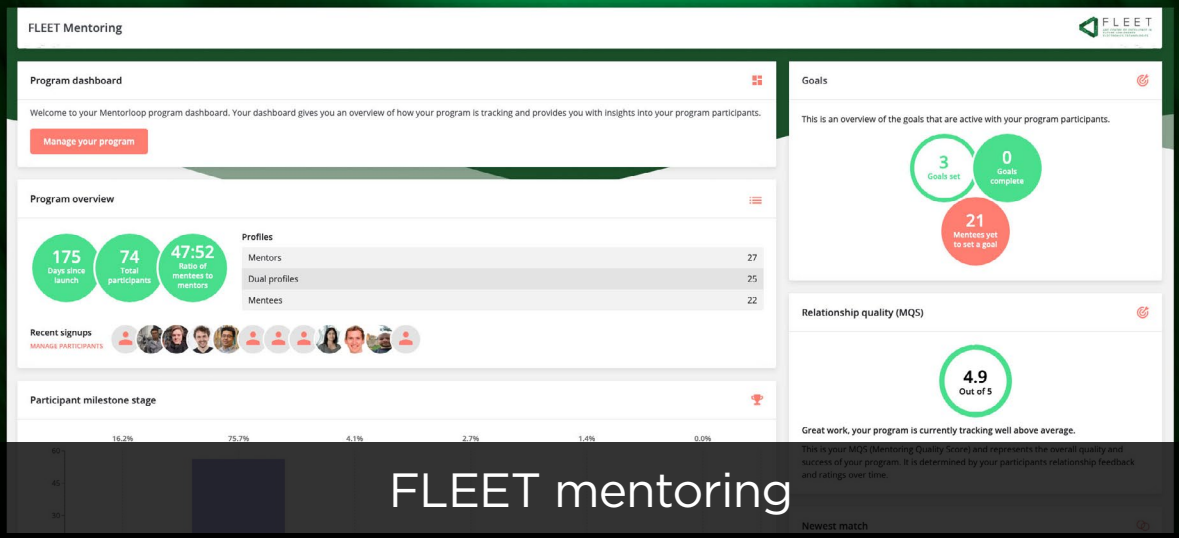
STAYING IN TOUCH

It is a testament to the sense of belonging at FLEET that almost all departing members choose to remain on the FLEET monthly newsletter list to stay in touch with the Centre.

FLEET alumni updates and career highlights are included in the Centre newsletter while 'Where are they now?' profiles show how our alums are applying their scientific and transferable skills in different areas, helping current PhD candidates envision more diverse future careers. Spotlights so far include:

- **Dr Paul Atkin** (ex RMIT) now working for Australian commercial scientific-equipment company Scitek
- **Dr Jesse Vaitkus** (ex RMIT) at a German commercial quantum software company
- **Dr Carlos Kuhn** (ex Swinburne) in government policy and consultancy, Canberra.
- **Dr Shilpa Sanwlani** (ex Swinburne) in financial crime risk management

Read more
FLEET.org.au



FLEET mentoring

FLEET provides mentoring to personnel across all career stages, covering areas such as induction, career advancement and planning, equity and diversity, professional development, entrepreneurship and research leadership skills.

Three mentoring models are offered:

- Participation in Centre governance committees
- Group mentoring via training sessions, for example, on manuscript preparation, grant writing, scientific presentation and research leadership
- Individual, goal-oriented mentoring, where members are individually matched to a mentor within FLEET (or in some cases external to FLEET) based on their needs. For example, guiding applications for promotion, grant writing, or providing career advice.

Since the program launch at the end of 2017, over 80 mentorship pairs have been formed. The new Mentorloop platform introduced in 2021 (see below) has 'reset' the statistics on mentor program participation with 37 active mentorship pairs, and provides a benchmark against which future progress can be measured.

Currently, 32% of students, 55% of research fellows, 67% of associate investigators and 65% of chief investigators are participating as either mentors or mentees in the FLEET mentoring program.

Four tailored, individual mentoring programs are available:

- For early-career researchers exploring career options
- In industry, for researchers considering work outside academia
- In academia, for those researchers looking at on building their academic careers
- For Women in FLEET, focusing on challenges unique to women in STEM.

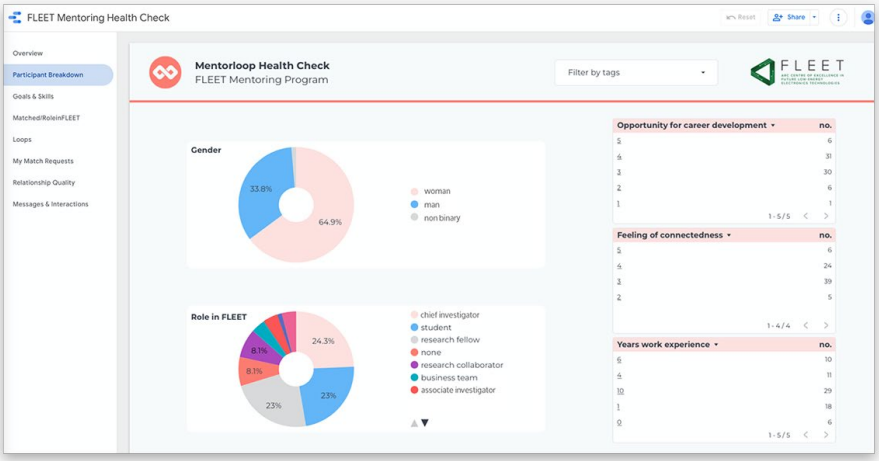
In addition to the above models, FLEET also leverages external mentoring programs to offer enhanced opportunities for its members, for example, winning scholarships from Women and Leadership Australia (WLA) for 11 members to advance their leadership skills in WLA's flagship program, Leading Edge.

Based on feedback from the Centre-wide survey of our members , FLEET has reviewed its mentoring strategy, with member feedback driving significant improvements to the program. In particular, both mentors and mentees requested more guidance or training.

FLEET has begun expanding the current mentor network to include international partners and industry representatives, and alumni with diverse career experiences, including four new industry mentors working in areas ranging from research and business to entrepreneurship.

We have begun to add new mentors external to FLEET, with the first four working in a range of university environments including business and research administration, and research. Other new mentors are senior researchers at international research institutions, including three from FLEET partner organisations.

FLEET has employed the mentoring management platform Mentorloop to facilitate existing mentoring programs, providing improved capacity to match mentor to mentee, and provide evaluation tools measuring the effectiveness of the Centre mentoring program. The platform also delivers training resources for both mentor and mentee to enhance engagement, added in response to member feedback.



Since its roll-out in September 2021, 87 FLEET members (38% of membership) have signed up to the Mentorloop program.

Engaging with policymakers: Science Meets Parliament

Engaging with politicians and policymakers

CASE STUDY

FLEET had four researchers at STA's annual Science Meets Parliament, which was run as an online event in 2021.

Engaging with politicians and other policymakers is key for any Centre of Excellence, and pitching to politicians is also a key skill for researchers, regardless of their career stage.

FLEET's four ECR delegates at Science Meets Parliament 2021 – Dr Eli Estrecho (ANU), Dr Peggy (Qi) Zhang (UNSW), Dr Gary Beane (Monash) and Dr Harley Scammell (UNSW) – were introduced to the machinery of government, received pitch and writing/communication training, and discussed research commercialisation and how to work with a mentor.

Participants also heard from a diverse mix of Australia's top scientists, including Chief Scientist Cathy Foley and Chief Defence Scientist Tanya Monro.

"SMP was great!" says UNSW postdoc Dr Harley Scammell. "Thanks FLEET for hooking me up with that one. The workshop on 'How to Marie Kondo your writing' was an absolute winner for me. I needed it."

"I learned a lot from both the speakers and the other participants," says ANU postdoc Dr Eli Estrecho. "The discussions were informative, especially for a physicist like me who has never thought about public policy. It was great hearing from Chief Scientists and Science Advisers from state, federal and foreign (Singapore, NZ, and Canada) governments."

"I also interacted with fellow participants working outside academia, for example, consultancies, CSIRO and Defence Science. It was enriching to know about their work and how they do their science," says Eli.

After the event, Science and Technology Australia (STA) arranged interviews with delegates' local MPs, which Harley described as "a candid conversation and quite fun".

Eli agreed, saying "My interview with Trent Zimmerman (MP North Sydney) was great. He was prepared, taking notes and very interactive. He seems to know what

he is talking about and he was familiar with data centres in his electorate so I really didn't have to explain everything."

Misha Schubert, CEO of STA, said: "Over the past week, it's also been a privilege to join some of the many meetings between our delegates and Parliamentarians. Each time, it's an inspiration to hear our STEM experts speak with passion and deep expertise in their fields. And it's terrific to see the engagement of so many Ministers, Shadow Ministers, MPs and Senators with the possibilities of STEM."

In talking to MPs and policymakers, and in perfecting their research 'pitch', Centre members put into action communication skills that have been keenly honed by the Centre's significant schools outreach programs.

"Our experience doing science outreach to schoolkids provides the opportunity for us to think and practise how to explain science to the public," explains UNSW postdoc Dr Peggy Zhang. "Also, we can feel some responsibility as a scientist in public science education."

"Schools outreach experiences have helped me get the right tone for my research pitch to MPs and policymakers," says Harley Scammel. "For example, I definitely stole a couple sentences and examples from what we'd presented a few years back at Scots College in Sydney."

FLEET was a silver sponsor of this year's Science Meets Parliament.

Read more
FLEET.org.au/
SMP2021

Idea Factory 2021

Perfecting the pitch

CASE STUDY

The 2021 Idea Factory challenged 36 early-career researchers to write more effective grant applications and learn to effectively communicate the value of their research to varied audiences.

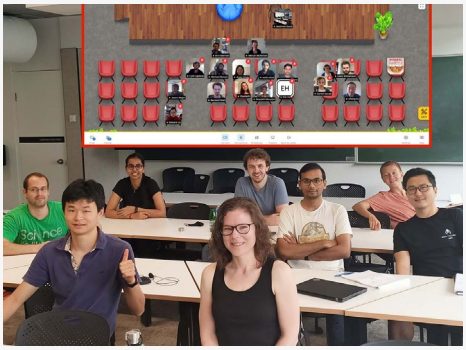
The workshop concentrated on developing researchers' ability to pitch their research – and get funded. This primarily involved:

- Improving grant writing skills and confidence, customising grants for different funding bodies
- Distilling key messages about a research project for target audiences
- Communicating the value of the research.

These key transferable skills will be valuable regardless of which career paths the researchers follow, whether in academia, industry, government or elsewhere.

The Idea Factory brings early-career researchers together to develop their skills in a fun and collaborative workshop. In 2021 the event ran online, taking advantage of that format to bring in Dr Merryn McKinnon from the ANU Centre for Public Awareness of Science to provide expert coaching on effective communication of science. Senior research mentors came in at strategic points in each group's preparation of their grant application to provide advice and support.

With Covid restricting interstate travel, FLEET and EQUS members from NSW and Victoria joined via the customisable online networking tool Kumospace, which allowed them to view presentations, follow in-room discussions, and network with others. Throughout 2020–21 FLEET has continued to trial new online platforms to maintain communication within the Centre.



Teams received feedback on their pitch from a mock panel, and practised pitching their research in shorter and shorter forms – one minute, then 30 seconds, then 15 seconds – to distil what was really the most impactful information.

The Idea Factory is a joint Centre of Excellence initiative involving the ARC Centres of Excellence for Engineered Quantum Systems (EQUS) and FLEET to provide training and networking opportunities for early-career researchers.

Post-training evaluation found that 86% of participants found the 2021 Idea Factory valuable, gaining confidence in their ability to write a grant application, and improving their ability to communicate their research.

> In the Idea Factory workshop, we were given instructions about how to write a good research proposal. The workshop's speakers and trainers were familiar with ARC grant applications, and had lots of experience.
>
> **IDEA FACTORY PARTICIPANT, 2021**

More at FLEET.org.au/Idea2021

Young researchers driving FLEET's training program

FLEET students and ECRs identifying and driving Centre training priorities

CASE STUDY

The ECR Working Group ensures that students and other Centre ECRs' voices are heard, and that their needs are met, in terms of the development programs delivered within the Centre.

The ECR Working Group is led by PhD students Abigail Goff (RMIT) and Vivasha Govinden (UNSW) along with Mark Edmonds from Monash, and Maedehsadat Mousavi, Dan Sando, Abhay Gupta and Marcus Goffage from UNSW.

Support for Working Group initiatives has been confirmed by the FLEET Executive Committee, which has provided the Group with a $10,000 dedicated annual budget to be used for ECR – and student-organised activities that support:

- Facilitating exchange of research ideas
- Enhancing scientific skills
- Expanding members' professional skills toolkit
- Extending professional and research networks.

The Working Group delivers quarterly updates to the FLEET Executive Committee on its activities.

A major current focus of the Working Group is the planning of an ECR Conference, to be run in conjunction to the major FLEET meeting in mid-2022. Comprehensive surveying of FLEET students and members has identified a suit of possible development to be delivered at the 2022 workshop, including sharing PhD tips and tricks, research sharing exercises, and industry skills.

PhD candidate Abigail Goff (RMIT) co-leads the ECR Working Group with Vivasha Govinden (UNSW), shown in banner image above

Such surveying ensures that training program meets the needs of FLEET students and ECRs. Another survey in early 2022 will specifically track translation and industry-related training needs.

The Group ran its first workshop in 2019. In 2020, they responded to Covid by moving from a planned in-person workshop to an collating online resources, to help members develop and continue to progress during pandemic conditions in 2020-21.

Since initiation, the Group has:

- Organised an ECR workshop in mid-2019
- Successfully lobbied for a collaborative travel grant scheme implemented in 2019 and a training grant scheme implemented in 2020
- Established a library of resources to build research and professional skills during Covid
- Secured training grants of up to $500 per member from the FLEET Education and Training Committee
- Surveyed Centre students to set training program to be delivered at dedicated ECR Conference 'for the ECRs and by the ECRs' in mid 2022.

We believe that this type of committee is most effective when driven by ECRs and students themselves, rather than by the Centre management, and FLEET has been encouraging our young researchers to join the existing working group.

PROF JARED COLE
FLEET Education and Training Committee Chair

FLEET's ECRs and students also drive Centre activities and policy through their involvement in all five of the Centre's special governance committees. This involvement in the Centre governance ensure that the views and needs of these cohorts are properly integrated into Centre strategy.

Presence on multiple committees also ensures proper movement of ideas from committee to committee. For example, suggestions developed in the Industry Relations Committee were able to be passed on the Education and Training Committee for implementation.

FLEET
ARC CENTRE OF EXCELLENCE IN FUTURE LOW-ENERGY ELECTRONICS TECHNOLOGIES

MEMBER PORTAL

DIRECTORY
KPI DASHBOARD
GRANTS AND AWARDS
ENVIRONMENTAL WORKING GROUP
FAQS
GOVERNANCE COMMITTEES
MEDIA & NEWS
MENTORING
OUTREACH
PRESENTATIONS
RESOURCES
TEMPLATES

MEMBER PORTAL

NEW TO FLEET? START HERE
MEMBER DIRECTORY
PRESENTATIONS
RESOURCES

— MORE

MEDIA & NEWS
POLICIES
GOVERNANCE
FAQS

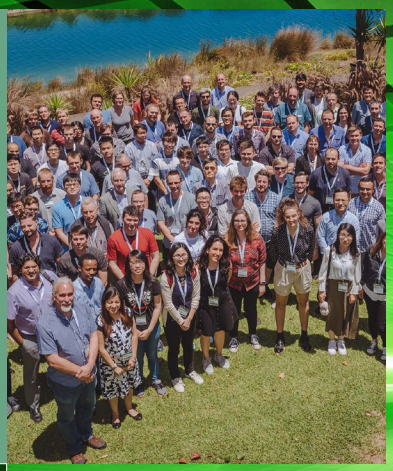
ENTER KPI CONTRIBUTIONS
FLEET CLEIVJER KPI PORTAL
FLEET STRATEGIC PLAN
STRATEGIC PLAN
CATCH UP ON FLEET
NEWS
ACCESS DCA EVENTS

LISTENING AND RESPONDING TO MEMBERS

PROFESSIONAL COUNSELLING SERVICE

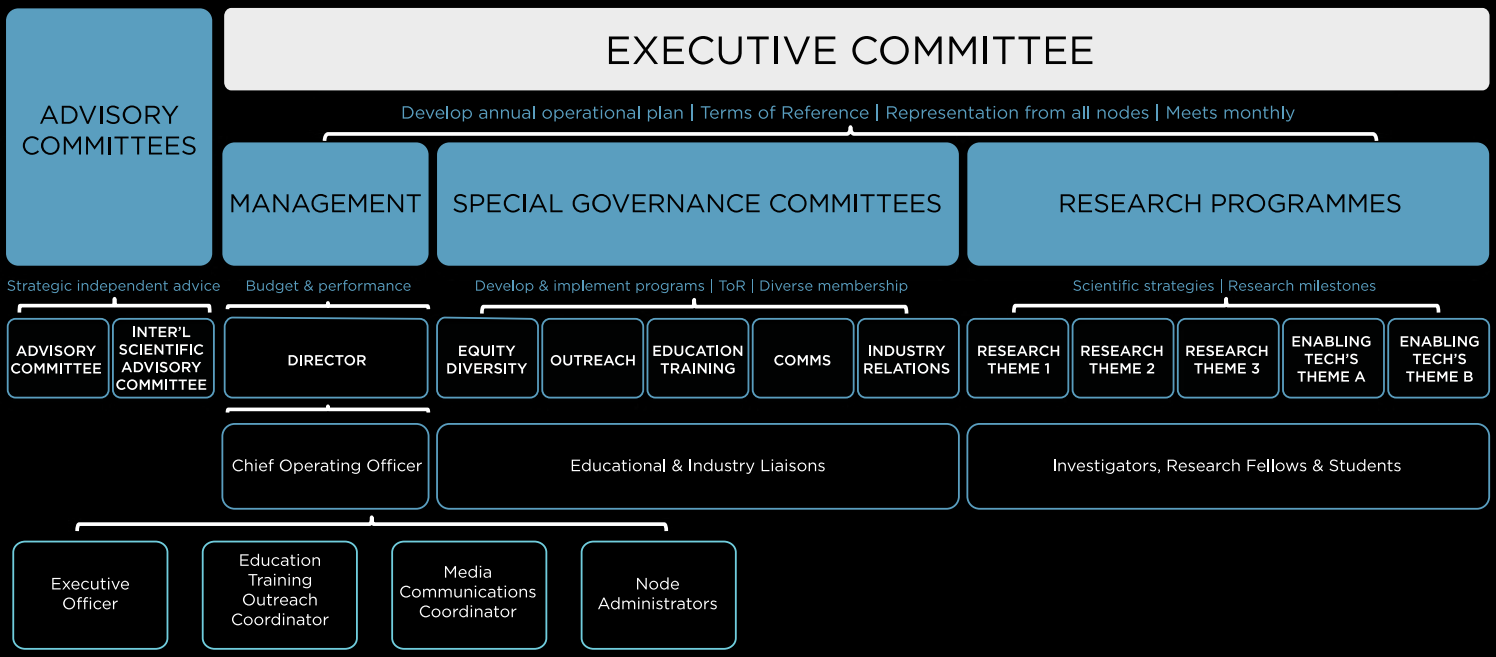
INSIDE FLEET

- Governance
- Strategic plan
- FLEET Executive team
- FLEET Business team



FLEET creates a work environment that develops its people and also values the contributions of individual members.

Governance – organisational chart



More at FLEET.org.au

Advisory Committee

FLEET's Advisory Committee helps the Executive Committee develop FLEET's strategic plan, which sets out how the Centre will meet its goals, in particular in creating linkages with industry, academia and government.

The Advisory Committee:

- Reviews FLEET's Annual Operating Plan
- Provides recommendations on financial management
- Provides recommendations on general management and operation, to ensure the Centre achieves its objectives
- Produces an annual report of strengths, weaknesses and opportunities.

FLEET ADVISORY COMMITTEE REPORT ON MID-TERM REVIEW

Following FLEET's 2021 mid-term review, led by the Australian Research Council, the FLEET Advisory Committee reviewed favourable and constructive feedback, and integration into the Centre's strategic plan. AC members congratulated the Centre on its achievements, it's results in the mid-term review, and in particular the new FLEET Translation Program commencing in 2022.

The Advisory Committee recommended that FLEET:

- Enhance the new translation program by engaging a team of experts
- Build further industry connections and develop internship programs
- Consider the legacy of FLEET research, and how to ensure a lasting impact. (This includes the specific inclusion of training.)
- Grow FLEET's mentoring program by engaging external links based on specific skills and knowledge transfer.

Education should not focus solely on the technology aspect of translation.... business aspects of translation should also be covered" – reference to the planned training component of the new FLEET Translation Program.

ELLEN WILLIAMS
FLEET Advisory Committee member

Rather than put a call out for people to join a mentoring program, FLEET should ask mentees how they can be assisted and then find people with that skill set or knowledge to be a mentor.

AN CHEN
FLEET Advisory Committee member

The Committee was introduced to FLEET's new legacy framework, highlighting six strategic priority areas of lasting impact after the Centre officially concludes.

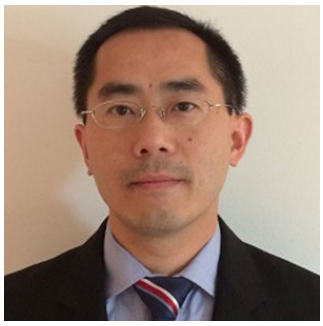
The Committee was also informed of FLEET progress in quantum-material collaborations, supporting member mental health and providing support around Covid issues, new ECR working group, and FLEET's new Diversity Fellowships.

AC members will continue leveraging their connections in the semiconductor and digital technology industries to help connect FLEET to potential research translation and mentoring networks.

ADVISORY COMMITTEE MEMBERS

Professor
Andrew Peele
Director Australian Synchrotron, Australia

Doctor
An Chen
Executive Director
Semiconductor Research Corporation, IBM, USA
Nanoelectronics Research Initiative, USA



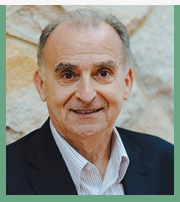
Professor
Ellen Williams
Distinguished Professor
University of Maryland, USA

Professor
Joanna Batstone
Director Monash Data Futures Institute

Professor
Luigi Colombo
Fellow
Texas Instruments, USA

Professor
Rebekah Brown
Senior Vice-Provost (Research)
Monash University

> FLEET has done a great job overall under the circumstances – reference to Covid interruptions and the FLEET response to supporting members.



LUIGI COLOMBO
FLEET Adviser, University of Texas

International Scientific Advisory Committee

FLEET's International Scientific Advisory Committee provides independent scientific advice to FLEET investigators, both directly and through the Centre Director.

The International Scientific Advisory Committee:

- Advises on the scientific directions of FLEET
- Benchmarks the quality of FLEET research against international standards
- Produces an annual report placing FLEET's progress in an international context and making recommendations for future directions.

INTERNATIONAL SCIENTIFIC ADVISORY COMMITTEE MEMBERS

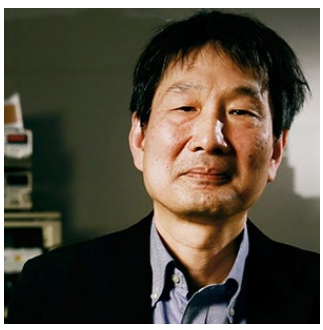
Professor
Wolfgang Ketterle
Professor of Physics
Massachusetts Institute of Technology, USA

Professor
Ali Yazdani
Professor of Physics
Princeton University, USA

Doctor
Esther Levy
Editor-in-Chief Advanced Materials Technologies

Professor
Francois Peeters
Professor of Physics
University of Antwerp

Professor
Hidenori Takagi
Director Max Planck Institute for Solid State Research, Germany



Sir
Kostya Novoselov
Professor of Physics
University of Manchester, UK

Sir
Michael Pepper
Professor of Physics
University College London, UK

Executive Committee

FLEET's Executive Committee oversees strategic plans for the Centre in accordance with the Australian Research Council (ARC) Funding Agreement and agreements with the Centre's collaborating organisations.

The Committee's responsibilities include:

- Overseeing general management and operation of the Centre
- Properly allocating funding
- Approving Centre activities
- Approving Centre intellectual property ownership
- Approving any amendments to the Centre budget and research program
- Promoting interactions between participants and partners across nodes and institutions
- Solving problems in the successful execution of the Centre's mission.

FLEET's Executive team comprises leaders of research themes and nodes, and committee chairs.

MICHAEL FUHRER, DIRECTOR

Michael is a pioneer in the study of electronic properties of two-dimensional (2D) materials, with extensive experience establishing and managing large, interdisciplinary research teams in Australia and the USA.

Michael directs implementation of FLEET's vision and mission and coordinates the three Research themes and two Enabling technologies.

With FLEET's Executive team, Michael implements the Centre's strategic plan, directing research, technology transfer, training and mentorship, and outreach.

An accomplished communicator, Michael represents FLEET's work to the research community, government, students, media and the public.

Michael is former director of the Monash Centre for Atomically Thin Materials and the Center for Nanophysics and Advanced Materials (University of Maryland).

TICH-LAM NGUYEN, CHIEF OPERATING OFFICER

Tich-Lam manages FLEET's operations and its business team. She is responsible for the Centre's financial and operational effectiveness and overseeing activities contributing to the development and delivery of its strategic goals.

Tich-Lam has a PhD in Chemistry from RMIT University and a Master of Management from the Melbourne Business School.

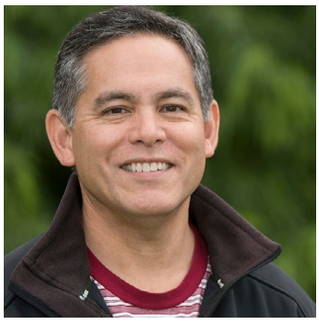
She has 15 years' experience in the higher education sector as a research centre manager, a laboratory manager and a researcher in nanoscience and nanotechnology.

EXECUTIVE COMMITTEE MEMBERS

Alex Hamilton
Deputy Director, Leader
Research theme 1 – UNSW

Elena Ostrovskaya
Leader
Deputy Chair, Equity and Diversity Committee
Research theme 2 – ANU

Kris Helmerson
Leader, Research theme 3
Monash



Xiaolin Wang
Leader, Enabling technology A – UOW

Lan Wang
Leader,
Enabling technology B – RMIT

Jeff Davis
Chair, Special Governance Committee – Equity and Diversity – Swinburne

Jared Cole
Chair, Special Governance Committee – Education and Training – RMIT

Julie Karel
Chair, Special Governance Committee – Outreach – Monash

David Cortie
Chair, Special Governance Committee – Communications – UOW

Torben Daeneke
Chair, Special Governance Committee – Industry Relations – RMIT

Strategic Plan

GOAL	MEASURE
1. ENABLE FRONTIER SCIENTIFIC DISCOVERIES	
1.1 Realise topologically-protected dissipationless transport of electrical current at room temperature, and novel devices based on the ability to switch on and off this dissipationless current	Project milestones and research outputs
1.2 Demonstrate excitonic dissipationless transport at elevated temperatures	Project milestones and research outputs
1.3 Investigate and realise systems that exhibit dissipationless transport by dynamically driving the systems out of equilibrium to explore new paradigms in electronics	Project milestones and research outputs
2. DEVELOP NEXT GENERATION OF SCIENCE LEADERS	
2.1 Develop world-class training & mentoring programs	Number of: • Participating members • External mentors • Research/professional development courses • Members and non-members participating in Centre training workshops • Mentoring programs organisational links in mentoring and training programs
2.2 Establish Centre succession planning for the centre	Established plan
2.3 Facilitate opportunities for research collaboration	Number of: • Travel grants facilitating collaboration • FLEET-wide colloquia, research seminars and workshops • Collaborative visits by FLEET partners • Intra-Centre expertise exchanges • New organisations collaborating with FLEET
2.4 Establish a collaborative culture within the Centre	Number of: • Travel grants facilitating collaboration • FLEET-wide colloquia, research seminars and workshops • Collaborative visits by FLEET partners • Intra-Centre expertise exchanges • New organisations collaborating with FLEET
2.5 Facilitate opportunities for career development in industry	Number of internship placements
2.6 Identify opportunities for members to be recognised	Number of awards and grants received by members for their scientific/leadership achievements
3. FACILITATE PARTNERSHIP DEVELOPMENT	
3.1 Establish international partnerships	Number of: • New research organisations collaborating with FLEET • Collaborative visits between members and collaborating organisations • Organisational links in training and mentoring programs • Organisational links in education and outreach programs
3.2 Establish links to industry and end users	Number of: • Briefings to end-users/industy • Internship placements with industy collaborators
3.3 Create a network to commercialise FLEET discoveries	Number of: • Relationships with end-users • Industry engagement workshops

4. FOSTER EQUITY / DIVERSITY IN STEM	
4.1 Foster a culture of equity and inclusiveness	Number of positive responses to annual surveys Level of compliance of all events organised/supported by FLEET with Centre's Equity and Diversity guidelines Increased participation of required training on equity, diversity and inclusion topics Awareness to recognise unacceptable behaviour and pathways to report
4.2 Increase diversity among all cohorts of researchers	Increased number of female researchers/HDR students across FLEET Level of compliance of FLEET HR policy in all Centre recruitments
4.3 Establish career support initiatives for women in FLEET and members with caring responsibilities	Gender ratio of ECRs staying in FLEET and science careers beyond FLEET Increased participation of FLEET researchers with family/carer responsibilities in FLEET/external events
4.4 Establish a women-specific mentoring network	Increased uptake of mentoring opportunities by women in FLEET
5. PROMOTE PUBLIC AWARENESS AND LITERACY OF FLEET SCIENCE	
5.1 Contribute to the scientific literacy and understanding of FLEET science among primary and secondary students and teachers	Evaluation of student/teacher literacy and understanding
5.2 To raise awareness of FLEET research among the general public	Evaluation of awareness at public engagement events Relevant social media to assess engagement
6. FACILITATE EFFECTIVE COMMUNICATION	
6.1 Support Centre strategic goals through internal communication using tools such as monthly newsletters	Improvement in internal newsletter readership
6.2 Engage with scientific research community through research stories published on key online science platforms and stakeholders' newsletters	Number of: • Research stories • Newsletter audience
6.3 Promote FLEET research and scientific literacy to public through web content and social media	Number of: • Social media audience reached on priority channels (Twitter, Facebook) • Mainstream media articles • Mentions of FLEET research in all media channels
6.4 Engage with key partners	Number of • Briefings to government agencies and NGOs • Public presentations annually
6.5 Empower FLEET members to communicate their own scientific work	Number of: • Non-peer reviewed articles • Members discussing their science on social media • Members presenting their research in a public forum • ECR and student members participating in Three-Minute Thesis, FameLab, Science in the Pub, and similar
6.6 Push the boundaries of what we're doing in communications, seeking and championing communications "best practice"	Number of new initiatives each year

For the full FLEET Strategic Plan go to FLEET.org.au/strategic-plan

Business team

> The FLEET Business Team does a great job in trying to bring the various nodes and groups together, and communicating the work of FLEET members.
>
> **FLEET MEMBER SURVEY**

BUSINESS TEAM MEMBERS

Tich-Lam Nguyen
Chief Operating Officer

Tich-Lam oversees FLEET's financial and operational effectiveness, aimed at delivering the Centre's strategic goals.

Tenille Ibbotson
Executive Officer

Tenille coordinates KPI and budget reporting across FLEET's seven nodes and provides administrative support to the Executive and governance committees.

Errol Hunt *Senior Communications Coordinator*

Errol coordinates FLEET's communications strategies, and communicates Centre mission and outcomes within FLEET, to the scientific community, to potential end users and to the public via media.

Jason Major *Senior Education and Training Coordinator*

Jason leads FLEET's education and training missions, student recruitment, career development programs, internship placement and outreach programs.

Cecilia Bloise *Node Administrator,* UNSW

Cecilia supports FLEET operations and reporting at UNSW and provides administrative support to node leader Prof Alex Hamilton.

Catherine Taylor Node Administrator, UNSW

Catherine supports FLEET operations and reporting at UNSW and provides administrative support to node leader Prof Alex Hamilton.

Nicci Coad
Node Administrator, RMIT

Nicci coordinates reporting of KPIs and budgets across the FLEET nodes and provides administrative support to node leader A/Prof Lan Wang and the RMIT team.

Tatiana Tchernova
Node Administrator, Swinburne

Tatiana provides administrative support and coordinates KPI reporting, as well as supporting node leader Prof Chris Vale.

Equity and Diversity Committee

FLEET fosters a culture of inclusiveness and works to promote diversity across the Centre.

FLEET's Equity and Diversity Committee sets and monitors the Centre's equity priorities, monitors our progress and tracks staff culture via surveys, and learns from equity best practice across the science sector. See Equity at FLEET.

> We are creating a respectful workplace that is free from discrimination and values the contributions of all members.
>
> **PROF MICHAEL FUHRER**
> *FLEET Director*

EQUITY AND DIVERSITY COMMITTEE MEMBERS

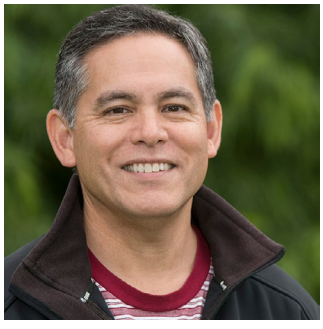
Jeff Davis
Committee Chair, Swinburne

Elena Ostrovskaya
Committee Deputy Chair, ANU

Alexander Nguyen
PhD Student, Monash

Tenille Ibbotson
Executive Officer, FLEET

Kris Helmerson
Chief Investigator**,** Monash



Lan Wang
Chief Investigator**,** RMIT

Matthew Davis
Chief Investigator, UQ

Meera Parish
Chief Investigator, Monash

Nicci Coad
Node Administrator, RMIT

Sumeet Walia
Scientific Associate Investigator, RMIT

Xiaolin Wang
Chief Investigator, UOW

Building future leaders: Education and Training Committee

FLEET is building future Australian science leaders among the Centre's early-career researchers and higher degree by research students.

FLEET's Education and Training Committee sets the Centre's strategies and sponsorship priorities, checking progress and development requirements. See Education at FLEET.

EDUCATION AND TRAINING COMMITTEE MEMBERS

Jared Cole
Committee Chair, RMIT

Matthew Davis
Committee Deputy Chair, Chief Investigator, UQ

Jason Major
Education and Outreach Coordinator, FLEET

Jan Seidel
Chief Investigator, UNSW

Jeff Davis
Chief Investigator, Swinburne

Jesper Levinsen
Research *Associate Investigator,* Monash

Lan Wang
Chief Investigator, RMIT

Oleh Klochan
Chief Investigator, UNSW

Peggy Qi Zhang
Research Fellow**,** UNSW

Xiaolin Wang
Chief Investigator, UOW

Prof Susan Coppersmith
Incoming Committee Chair**,** UNSW

FLEET has an extensive network of experts worldwide who are affiliated with the Centre. This provides unique education opportunities for our students and researchers, where they can learn from the world's best researchers in the field.

PROF JARED COLE
FLEET Education and Training Committee Chair

Spreading a passion for science: Outreach Committee

FLEET will promote public awareness and literacy of FLEET science and inspire more participation in science.

FLEET's Outreach Committee sets outreach strategy and determines appropriate outreach activities and public events to support. See Engage with FLEET section.

OUTREACH COMMITTEE MEMBERS

Meera Parish
Committee Chair (January-August), Monash

Julie Karel
Committee Chair, Monash

Nikhil Medhekar
Committee Deputy Chair and Chief Investigator, Monash

Jason Major
Training & Outreach Coordinator, FLEET

Chris Vale
Chief Investigator, Swinburne

Dimi Culcer
Chief Investigator, UNSW

Eliezer Estrecho
Research Fellow, ANU

Errol Hunt
Senior Communications Coordinator, FLEET

Matthew Davis
Chief Investigator, UQ

Wafa Afzal
PhD Student, UOW

Karina Hudson
Scientific Associate Investigator, UNSW

> FLEET has excellent resources regarding outreach, and many people excited about communicating with the general public. Easy access to these resources has made outreach much more accessible than doing these things independently.
>
> **FLEET MEMBER SURVEY**

Sharing FLEET news and science: Communications Committee

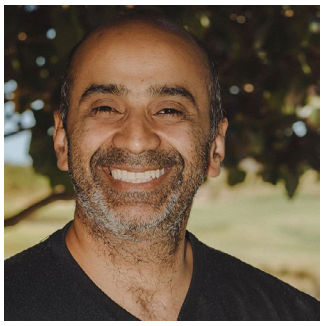
FLEET's Communications Committee gathers information and leads on stories from diverse nodes, feeds these stories through to the communications coordinator, channels feedback from the nodes, and develops strategies to communicate FLEET research to the wider research community, partners, stakeholders, potential end users and the public. See the Engage with FLEET section.

> The communications team do a good job advertising seminars, especially around Covid. In terms of collaboration, the past 12 months have seen the fruits of the collaboration that started in 2017, which is a strength.
>
> **FLEET MEMBER SURVEY**

COMMUNICATIONS COMMITTEE MEMBERS

David Cortie
Committee Chair, UOW

Nagy Valanoor
Committee Deputy Chair, Chief Investigator, UNSW



Errol Hunt
Senior Communications Coordinator, FLEET

Cecilia Bloise
Node Administrator, UNSW

Chutian Wang
PhD Student, Monash

Jackson Smith
Research Associate Investigator, RMIT

Jared Cole
Chief Investigator, RMIT

Jeff Davis
Chief Investigator, Swinburne

Matthias Wurdack
PhD Student, ANU

Stuart Earl
Research Fellow, Swinburne

Vivasha Govinden
PhD Student, UNSW

Karina Hudson
Incoming Committee Chair, UNSW

Research translation: Industry Relations Committee

FLEET's Industry Relations Committee's tasks are to:

- Ensure FLEET research outcomes are fed into affiliated and broader industries
- Engage with current industrial partners and attract future industry partners
- Establish the ground for translation and eventual commercialisation of research outputs, with maximum benefit to the consumers. See Research Translation.

INDUSTRY RELATIONS COMMITTEE MEMBERS

Torben Daeneke
Committee Chair, RMIT

Stuart Earl
Committee Deputy Chair, Research Fellow, Swinburne

Errol Hunt
Senior Communications Coordinator, FLEET

Jian-Zhen Ou
Scientific Associate Investigator, RMIT

Kourosh Kalantar-zadeh
Chief Investigator, UNSW

Matthew Gebert
PhD Student, Monash

Mitchell Conway
PhD Student, Swinburne

Tich-Lam Nguyen
Chief Operating Officer, FLEET

Xiaolin Wang
Chief Investigator, UOW

> The Industry Relations Committee leads engagement with industrial partners and establishes groundwork for ultimate translation and commercialisation of FLEET's science into affiliated industries.

PROF KOUROSH KALANTAR-ZADEH
IR Committee member

Education and industry liaisons

FLEET works with specialised educational and outreach liaisons.

EDUCATION AND INDUSTRY LIAISONS

Dr Eroia Barone-Nugent
Australian Institute of Policy and Science

Dr Toby Bell
Monash University

Camille Thomson
Australian Institute of Policy and Science

Dr Andrew Hind
General Manager of Molecular Spectroscopy, Agilent Technologies

Mark Muzzin
CSIRO

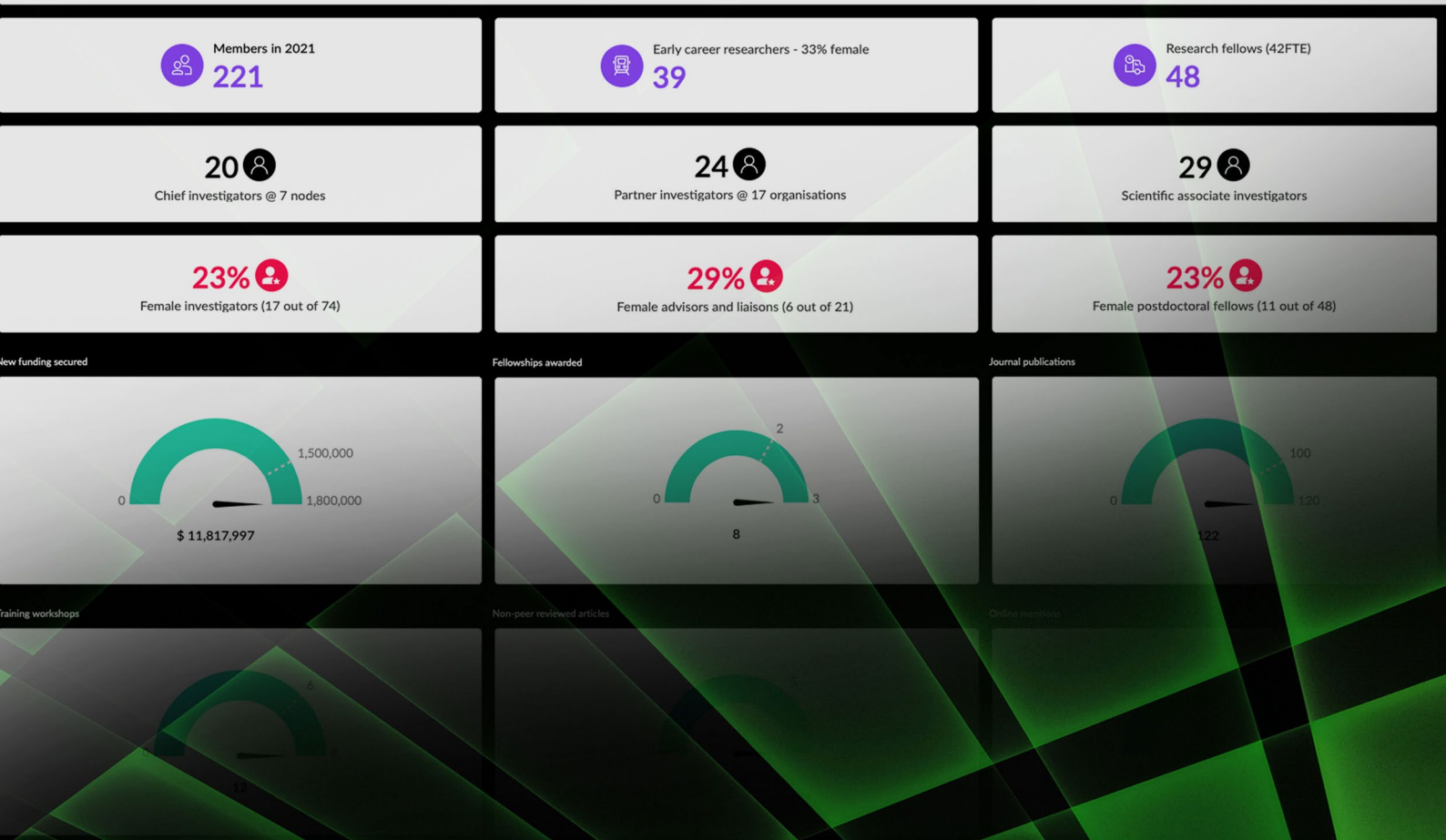
Chris Gilbey
CEO Imagine Intelligent Materials Pty Ltd

Dr Jim Patrick
Chief Scientist and Senior Vice President Research and Applications, Cochlear Limited

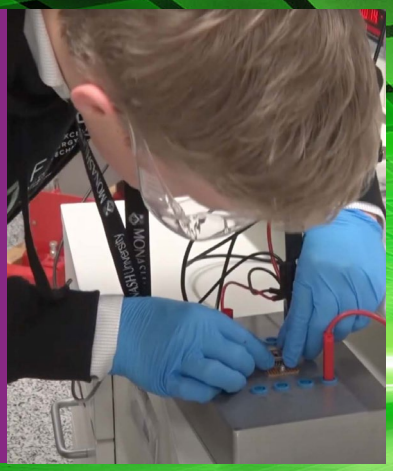
Dr Steven Duvall
Chief Technology Officer and General Manager of Technology Development, Silanna

458 FLEET research outputs from the Altmetric database

Altmetric - view attention timeline



PERFORMANCE

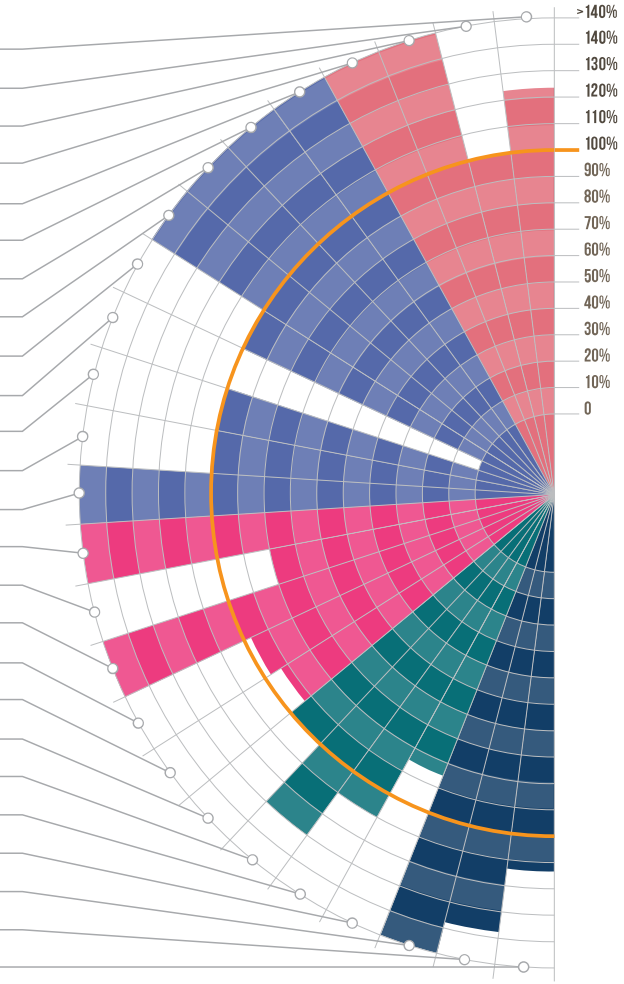


Key performance indicators

PERFORMANCE MEASURES

- Research Outputs
- Education and Training
- FLEET Research Personnel
- Mentoring
- Partnership Development

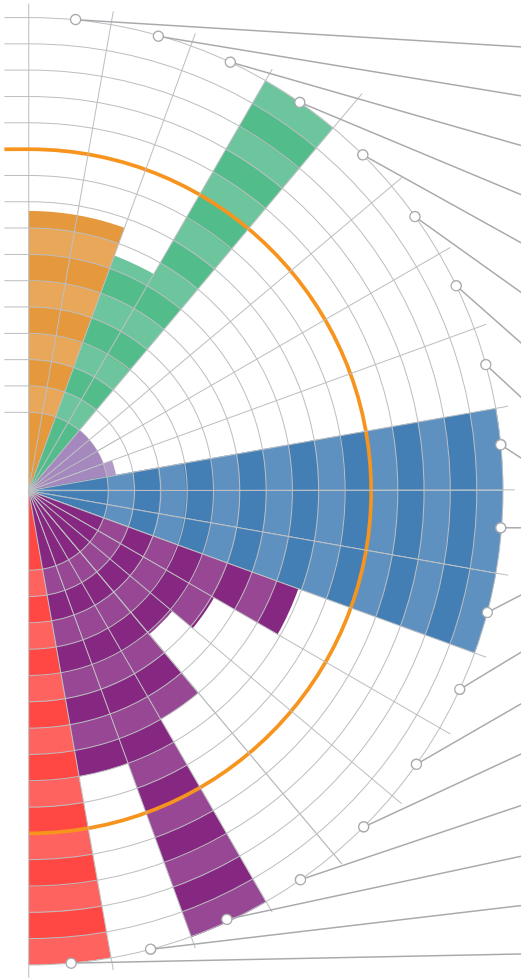
STANDARD KPI	Target	Actual	% Met
Journal articles	100	122	122%
Patents applied	2	2	100%
Technical briefings presented to targeted industry groups	1	5	500%
Publications in journals with IF >7	20	78	390%
Research & professional development courses	6	12	200%
Training workshops on diversity and gender equity	1	2	200%
Centre attendees at training workshops	150	1254	836%
Non-Centre attendees at training workshops	150	506	337%
Workshops held within Australia	2	2	100%
Workshops held outside Australia	2	0	0%
National symposium & conferences facilitated	1	1	100%
International symposium & conferences facilitated	1	1	100%
Industry engagement workshops to be held	1	3	300%
Postdoctoral researchers (total FTE)	20	43	215%
Honours students (total)	5	4	80%
PhD students (total)	30	55	183%
Associate investigators (total)	30	29	97%
PhD completions	15	14	93%
Mentoring programs offered by the Centre	4	4	100%
Mentors within the Centre	40	52	130%
Mentors external to the Centre	10	11	110%
FLEET members participating as mentees	55	47	85%
Organisational links in training and mentorship programs	5	20	400%
Presentations to stakeholders	30	41	137%
New organisations collaborating with or involved in, the Centre	8	9	113%



Key performance indicators

PERFORMANCE MEASURES

- Gender equity
- Recognition
- Partnership development
- FLEET PR and Marketing
- Outreach
- New funding



% Met	Actual	Target	CENTRE SPECIFIC KPI
77%	23%	30%	Percentage of women HDRs in FLEET
73%	22%	30%	Percentage of women ECRs in FLEET
65%	26	40	Invited talks at international conferences
400%	8	2	New fellowships awarded to CIs, ECRs and AIs
0%	0	10	International students and ECRs visiting FLEET
0%	0	30	Senior investigators – International visitors FLEET
0%	0	10	Chief Investigators visiting partners
13%	2	15	ECRs & HDRs students visiting partners
500%	25	5	Non-peer reviewed works by FLEET members
165%	412	250	Mentions of FLEET research in the media
1137%	9098	800	New users to Centre website, monthly average
78%	941	1200	Hours spent in outreach activities
48%	954	2000	Primary/secondary students reached in outreach activities
39%	29	75	Primary/secondary teachers reached in outreach activities
70%	3478	5000	Public reached in outreach activities
180%	18	10	Organisational links in education and outreach programs
80%	8	10	End-user relationships established
788%	11,818	1500	Other research income secured by Centre staff ('000)

KPIs IN DETAIL

KEY PERFORMANCE INDICATORS	TARGET 2021	ACTUAL 2021
RESEARCH OUTPUTS		
Journal articles	100	122
Patents applied	2	2
Technical briefings presented to targeted industry groups	1	5
Publications in journals with IF >7	20	78
EDUCATION & TRAINING		
Research & professional development courses	6	12
Training workshops on diversity and gender equity	1	2
Centre attendees at training workshops	150	1254
Non-Centre attendees at training workshops	150	506
Workshops held within Australia	2	2
Workshops held outside Australia	2	0*
National symposium & conferences facilitated	1	1
International symposia & conferences facilitated	1	1
Industry engagement workshops to be held	1	3
FLEET RESEARCH PERSONNEL		
Postdoctoral researchers (total FTE)	20	43
Honours students (total)	5	4
PhD students (total)	30	55
Associate investigators (total)	30	29#
PhD completions	15	14*
MENTORING		
Mentoring programs offered by the Centre	4	4
Mentors within the Centre	40	52
Mentors external to the Centre	10	11
FLEET members participated as mentees	55	47
PARTNERSHIP DEVELOPMENT		
Organisational links in training and mentorship programs	5	20
Presentations to stakeholders	30	41
New organisations collaborating with, or involved in, the Centre	8	9
GENDER EQUITY		
Percentage of women HDRs in FLEET	30%	23%*
Percentage of women ECRs in FLEET	30%	22%*
RECOGNITION		
Invited talks at international conferences*	40	26*
New fellowships awarded to CIs, ECRs and AIs	2	8

PARTNERSHIP DEVELOPMENT		
International students and ECRs visiting FLEET	10	0*
Senior investigators - International visitors to FLEET	30	0*
Chief investigators visiting partners	10	0*
ECRs & HDR students visiting partners	15	2*
FLEET PR & MARKETING		
Non-peer reviewed works written by FLEET members	5	25
Mentions of FLEET research in the media	250	412
Unique hits to Centre website, monthly average	800	9098
OUTREACH		
Hours spent in outreach activities	1200	941*
Primary/Secondary students reached in outreach activities	2000	954*
Primary/Secondary teachers reached in outreach activities	75	29*
Public reached in outreach activities	5000	3478*
Organisational links in education and outreach programs	10	18
End-user relationships established	10	8*
NEW FUNDING		
Other research income secured by Centre staff (thousands)	1500	11,818

* KPI targets unmet due to impact of the global pandemic: conferences, meetings and public events cancelled, travel bans, social distancing requirements, lock-downs and laboratory shut-downs and Centre reduced requirement of member outreach hour contributions as a mitigation strategy to look after members' mental health and wellbeing.

KPI target unmet due to the resignation of two international AIs, whose research programs no longer align with FLEET.

Research outputs

PATENTS

FLEET MEMBERS INVOLVED	PATENT TITLE	PATENT IDENTIFICATION NUMBER	DATE FILED
Michael Fuhrer	Negative capacitance topological quantum field-effect transistor	2021903614	11/11/21
Alex Hamilton, Oleh Klochan, Daisy Qingwen Wang, Yonatan Ashlea-Alava	Semiconductor device with a crystal heterostructure and an associated process	2021902137	13/7/21

PEER-REVIEWED PUBLICATIONS

1. Adlong, H. S.; Liu, W. E.; Turner, L. D.; Parish, M. M.; Levinsen, J. *Signatures of the Orthogonality Catastrophe in a Coherently Driven Impurity. Phys. Rev. A* **2021**, 104 (4), 043309. DOI 10.1103/PhysRevA.104.043309. Impact factor less than 4 *
2. Alidoosti, M.; Esfahani, D. N.; Asgari, R. *Charge Density Wave and Superconducting Phase in Monolayer InSe. Phys. Rev. B* **2021**, 103 (3), 035411. DOI .10.1103/PhysRevB.103.035411. Impact factor less than 4
3. Allioux, F.-M.; Merhebi, S.; Tang, J.; Zhang, C.; Merenda, A.; Cai, S.; Ghasemian, M. B.; Rahim, M. A.; Maghe, M.; Lim, S.; Zhang, J.; Hyde, L.; Mayyas, M.; Cunning, B. V.; Ruoff, R. S.; Kalantar-zadeh, K. *Carbonization of Low Thermal Stability Polymers at the Interface of Liquid Metals. Carbon* **2021**, 171, 938–945. DOI 10.1016/j.carbon.2020.09.062. Impact factor 7 to 10
4. Alosaimi, G.; Shin, S. J.; Chin, R. L.; Kim, J. H.; Yun, J. S.; Seidel, J. *Probing Charge Carrier Properties and Ion Migration Dynamics of Indoor Halide Perovskite PV Devices Using Top- and Bottom-Illumination SPM Studies. Adv. Energy Mater.* **2021**, 2101739. DOI 10.1002/aenm.202101739. Impact factor >10
5. Alsaif, M. M. Y. A.; Haque, F.; Alkathiri, T.; Krishnamurthi, V.; Walia, S.; Hu, Y.; Jannat, A.; Mohiuddin, M.; Xu, K.; Khan, M. W.; Ma, Q.; Wang, Y.; Pillai, N.; Murdoch, B. J.; Dickey, M. D.; Zhang, B. Y.; Ou, J. Z. *3D Visible-Light-Driven Plasmonic Oxide Frameworks Deviated from Liquid Metal Nanodroplets. Adv. Funct. Mater.* **2021**, 2106397. DOI 10.1002/adfm.202106397. Impact factor>10 *
6. Ashlea Alava, Y.; Wang, D. Q.; Chen, C.; Ritchie, D. A.; Klochan, O.; Hamilton, A. R. *High Electron Mobility and Low Noise Quantum Point Contacts in an Ultra-Shallow All-Epitaxial Metal Gate GaAs/Al x Ga 1- x As Heterostructure. Appl. Phys. Lett.* **2021**, 119 (6), 063105. DOI 10.1063/5.0053816. Impact factor less than 4
7. Ashlea Alava, Y.; Wang, D. Q.; Chen, C.; Ritchie, D. A.; Ludwig, A.; Ritzmann, J.; Wieck, A. D.; Klochan, O.; Hamilton, A. R. *Ultra-Shallow All-Epitaxial Aluminum Gate GaAs/Al x Ga 1- x As Transistors with High Electron Mobility. Adv. Funct. Mater.* **2021**, 2104213. DOI 10.1002/adfm.202104213. Impact factor >10
8. Bakaul, S. R.; Prokhorenko, S.; Zhang, Q.; Nahas, Y.; Hu, Y.; Petford-Long, A.; Bellaiche, L.; Valanoor, N. *Freestanding Ferroelectric Bubble Domains. Adv. Mater.* **2021**, 2105432. DOI 10.1002/adma.202105432. Impact factor >10 *
9. Bake, A.; Rezoanur Rahman, M.; Evans, P. J.; Cortie, M.; Nancarrow, M.; Abrudan, R.; Radu, F.; Khaydukov, Y.; Causer, G.; Callori, S.; Livesey, K. L.; Mitchell, D.; Pastuovic, Z.; Wang, X.; Cortie, D. *Structure and Magnetism of Ultra-Small Cobalt Particles Assembled at Titania Surfaces by Ion Beam Synthesis. Applied Surface Science* **2021**, 570, 151068. DOI 10.1016/j.apsusc.2021.151068. Impact factor 4 to 7# *
10. Bhalla, P.; Deng, M.-X.; Wang, R.-Q.; Wang, L.; Culcer, D. *Nonlinear Ballistic Response of Quantum Spin Hall Edge States. Phys. Rev. Lett.* **2021**, 127 (20), 206801. DOI 10.1103/PhysRevLett.127.206801. Impact factor 7 to 10
11. Bhattacharyya, S.; Akhgar, G.; Gebert, M.; Karel, J.; Edmonds, M. T.; Fuhrer, M. S. *Recent Progress in Proximity Coupling of Magnetism to Topological Insulators. Adv. Mater.* **2021**, 33 (33), 2007795. DOI 10.1002/adma.202007795. Impact factor >10 *
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Polaritons. Phys. Rev. B **2021**, 104 (3), 035304. DOI 10.1103/PhysRevB.104.035304. Impact factor 4 to 7 *

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18. Conti, S.; Saberi-Pouya, S.; Perali, A.; Virgilio, M.; Peeters, F. M.; Hamilton, A. R.; Scappucci, G.; Neilson, D. Electron–Hole Superfluidity in Strained Si/Ge *Type II Heterojunctions. npj Quantum Mater.* **2021**, 6 (1), 41. https://doi.org/10.1038/s41535-021-00344-3. DOI 10.1038/s41535-021-00344-3. Impact factor >10#
19. Cullen, J. H.; Bhalla, P.; Marcellina, E.; Hamilton, A. R.; Culcer, D. *Generating a Topological Anomalous Hall Effect in a Nonmagnetic Conductor: An In-Plane Magnetic Field as a Direct Probe of the Berry Curvature. Phys. Rev. Lett.* **2021**, 126 (25), 256601. DOI 10.1103/PhysRevLett.126.256601. Impact factor 7 to 10#
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28. Efimkin, D. K.; Kargarian, M. *Topological Spin-Plasma Waves. Phys. Rev. B* **2021**, 104 (7), 075413. DOI 10.1103/PhysRevB.104.075413. Impact factor 4 to 7
29. Efimkin, D. K.; Laird, E. K.; Levinsen, J.; Parish, M. M.; MacDonald, A. H. *Electron-Exciton Interactions in the Exciton-Polaron Problem. Phys. Rev. B* **2021**, 103 (7), 075417. DOI 10.1103/PhysRevB.103.075417. Impact factor less than 4#*
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33. Gbadamasi, S.; Mohiuddin, M.; Krishnamurthi, V.; Verma, R.; Khan, M. W.; Pathak, S.; Kalantar-zadeh, K.; Mahmood, N. *Interface Chemistry of Two-Dimensional Heterostructures – Fundamentals to Applications. Chem. Soc. Rev.* **2021**, 50 (7), 4684–4729. DOI 10.1039/D0CS01070G. Impact factor >10
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DOI Article Digital object identifier

**** publications involving associate investigators***

 # publications involving partner investigators

Impact factor at time of publication

Awards, honours and grants

MEMBERS INVOLVED	NAME OF AWARD GRANT SCHEME	DESCRIPTION OF AWARD / GRANT	FUNDING SOURCE	GRANT ID	TOTAL AMOUNT OF FUNDING (AUD)
Priyank Kumar	ARC DECRA Fellowship	A predictive, ab initio design of enhanced plasmonic photocatalysts.	Other ARC grants	DE210101259	360,000
Matthew Reeves	ARC DECRA Fellowship	Calming the Superfluid Storm: Taming Turbulence in Superfluid Devices.	Other ARC grants	DE220101548	415,000
Qingdong Ou	ARC DECRA Fellowship	Engineering twisted two-dimensional materials for mid-infrared detectors.	Other ARC grants	DE220100154	426,000
Eliezer Estrecho	ARC DECRA Fellowship	Mixing light and matter with complex gauge fields.	Other ARC grants	DE220100712	427,562
Nikhil Medhekar	ARC Discovery Project	From One Structure to Another for Improved Materials Design.	Other ARC grants	DP210101451	470,000
Zengji Yue, David Cortie	ARC Discovery Project	Hot Topic: Quantum Design of Phononic Heat Filters.	Other ARC grants	DP210101436	315,000
Jeff Davis	ARC Discovery Project	Multidimensional Coherent Spectroscopy of Strongly Correlated Materials.	Other ARC grants	DP210102050	410,000
Jan Seidel	ARC Discovery Project	Multiferroic Skyrmion Materials for Next Generation Nanoelectronics.	Other ARC grants	DP210102554	240,000
Susan Coppersmith	ARC Discovery Project	Topological superconductivity and spin electronics in silicon and germanium.	Other ARC grants	DP210101608	580,000
Jan Seidel	ARC Discovery Project	Topotactic Control of Magnetism in Multiferroic and Skyrmion Materials.	Other ARC grants	DP210102346	437,000
Chris Vale	ARC Discovery Project	Transport and impurity dynamics in a unitary Fermi gas.	Other ARC grants	DP210101652	428,000
Zhi Li	ARC Future Fellowship	Iron-based high-temperature topological superconductors.	Other ARC grants	FT210100844	802,288
Kourosh Kalantar-Zadeh, Nikhil Medhekar	ARC Industry Transformational Research Hub	ARC Research Hub for Advanced Manufacturing with 2D Materials (AM2D).	Other ARC grants	IH210100025	4,379,165
Toby Bell	ARC LIEF	A fast fluorescence lifetime imaging microscope to track protein dynamics.	Other ARC grants	LE210100046	289,381
Kourosh Kalantar-zadeh, Xiaolin Wang	ARC LIEF	A platform for probing nanoscale magnetic states under multiple actuations.	Other ARC grants	LE210100086	489,250

Lan Wang, Jian-zhen Ou, Torben Daeneke	ARC LIEF	Magnetometry Facility for Molecular and Nanoscale Materials.	Other ARC grants	LE210100009	620,000
Xiaolin Wang, Kirrily Rule, Zengji Yue, David Cortie	ARC Linkage Project	Functional topological materials for superior thermoelectric applications	Other ARC grants	LP200201096	400,551
Iolanda Di Bernardo	Juan de la Cierva Fellowship	The Juan de la Cierva fellowship is highly competitive, is similar to the Australian DECRA fellowship. Iolanda will be working at the IMDEA Nanociencia Institute in Madrid, an interdisciplinary research Centre dedicated to the exploration and applications of nanoscience and nanotechnology.	Other external funding		
Jesper Levinsen	Outstanding Referee, American Physical Society	Recognising outstanding referees who have demonstrated exceptional work in the assessment of manuscripts published in the American Physical Society journals.	Other external funding		
Zengji Yue	Prioritising Emerging Research Leaders Fellowship - University of Wollongong	The PERL Fellowships support emerging researchers on key projects under the mentorship of established researchers. Supporting academic staff levels A-C, designed to mitigate the impact of COVID-19 on Australia's research workforce, initiatives and activities.	Other external funding		
Jared Cole	Royal Society of New Zealand, Catalyst International Leaders Fellowship	Using exotic materials for novel spintronic and superconducting devices: Electronics underpin the modern world, from the phones in our pockets to the supercomputers that model the weather.	Other external funding	21-VUW-005-ILF	138,000
Semonti Bhattacharyya	The Early Career Women Writing (ECWW) workshop Alumni SILVER Award	Awards set for the former attendees of the Early Career Women in STEMM Writing Workshop based on career achievements since attending the workshop.	Other external funding		200
Alex Hamilton, Oleh Klochan, Daisy Qingwen Wang, Yonatan Ashlea-Alava	UNSW IP lodgement support	Supporting provisional patent lodgement costs	University of New South Wales Sydney		6,100
Alex Hamilton, Oleh Klochan, Daisy Qingwen Wang	UNSW Research Infrastructure Scheme (RIS)	Thin film metal evaporator for P-type (hole) quantum devices and III-V solar cells".	University of New South Wales Sydney		170,000
Vivasha Govinden	UNSW Science PhD Writing Scholarship	Supporting student during the examination period of PhD thesis so they can focus on preparing journal articles for publications.	University of New South Wales Sydney		7,500

Baoyue Zhang	Vice-Chancellor's Prize for Research Excellence – Higher Degree by Research	The Vice-Chancellor's Prize for Research Excellence – HDR (Higher Degree by Research) recognises an outstanding HDR candidate who has achieved the highest levels of excellence in research during the completion of their degree.	RMIT University		3,000
Maedehsadat Mousavi	Women Leadership Australia scholarship - Leading Edge	Leadership training and mentoring	Other external funding		1,000
Abigail Goff	Women Leadership Australia scholarship - Leading Edge	Leadership training and mentoring	Other external funding		1,000
Tenille Ibbotson	Women Leadership Australia scholarship - Leading Edge	Leadership training and mentoring	Other external funding		1,000
Nicci Coad	Women Leadership Australia scholarship - Leading Edge	Leadership training and mentoring	Other external funding		1,000
Semonti Bhattacharyya	Young scientist representative at World Laureates Forum (WLF)	Selected as young scientist representative from Monash University at World Laureates Forum (WLF)	Other external funding		

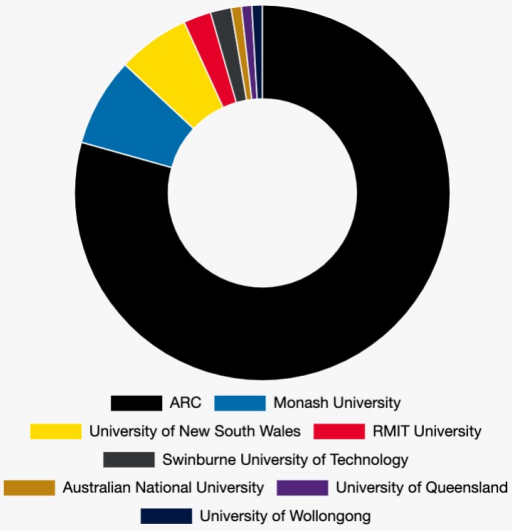
Centre finance

2021-2022 FINANCIAL STATEMENT

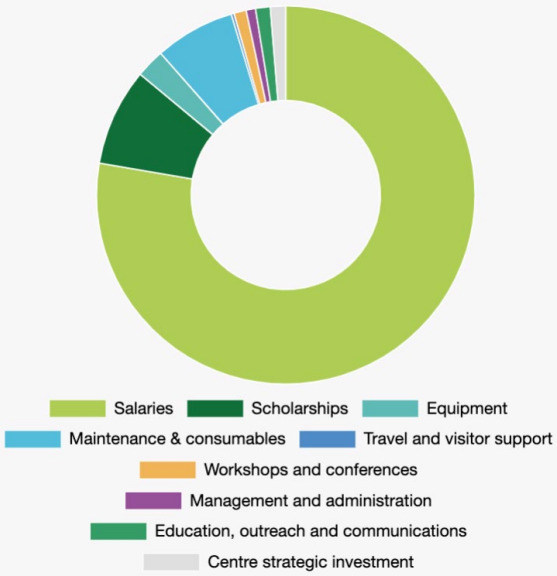
REPORTING PERIOD	2021	2022 CURRENT PERIOD
Carry Forward From 2020	**4,487,573**	
INCOME	**ACTUAL $**	**FORECAST $**
ARC (includes indexation)	5,167,675	4,800,000
Monash University	496,000	496,000
University of New South Wales	404,667	404,667
RMIT University	155,000	154,667
Swinburne University of Technology	116,000	116,000
Australian National University	58,000	58,000
University of Queensland	58,000	58,000
University of Wollongong	58,000	58,000
TOTAL INCOME	**6,513,342**	**6,145,334**
EXPENDITURE	**ACTUAL $**	**FORECAST $**
Personnel	4,495,136	5,300,000
- Salaries	4,060,206	
- Scholarships	434,930	
Equipment	129,472	117,474
Maintenance & consumables	357,400	393,798
Travel and visitor support	12,378	334,233
Other	230,681	
- Workshops and conferences	55,623	140,000
- Management and administration	41,389	40,000
- Education, outreach and communications	64,989	104,000
- Centre strategic investment	68,681	360,000
TOTAL EXPENDITURE	**5,225,068**	**6,789,505**
CARRIED FORWARD TO 2022	**5,775,848**	

FINANCIAL SUMMARY

2021 ACTUAL INCOME



2021 ACTUAL EXPENDITURE



COLLABORATING ORGANISATION	2021 ACTUAL $	2022 COMMITMENT $
Monash University	997,929	751,971
University of New South Wales Sydney	862,383	768,588
RMIT University	626,741	370,560
Swinburne University of Technology	394,315	342,152
Australian National University	166,391	73,628
University of Queensland	66,099	173,858
University of Wollongong	168,260	146,127
Australian Nuclear Science and Technology Organisation	440,205	374,000
Australian Synchrotron	241,704	240,465
Beijing Computational Science and Research Center, China	48,000	63,000
California Institute of Technology, USA	26,800	26,800
China High Magnetic Field Laboratory, China	16,000	20,000
Joint Quantum Insitute, USA	106,970	30,000
MacDiarmid Institute - Victoria University of Wellington, New Zealand	18,000	20,000
Max Planck Institute of Quantum Optics, Germany	62,110	34,425
National University of Singapore, Singapore	62,984	99,000
Tsinghua University, China	66,854	118,500
Universitat Wurzburg, Germany	19,512	19,512
University of Camerino, Italy	28,258	14,130
University of Colorado Boulder, USA	17,000	17,000
University of Maryland, USA	42,700	62,700
University of Texas, USA	18,000	31,000
Wroclaw University of Science and Technology, Poland	26,800	26,800
TOTAL IN-KIND CONRIBUTIONS	**4,524,015**	**3,824,216**

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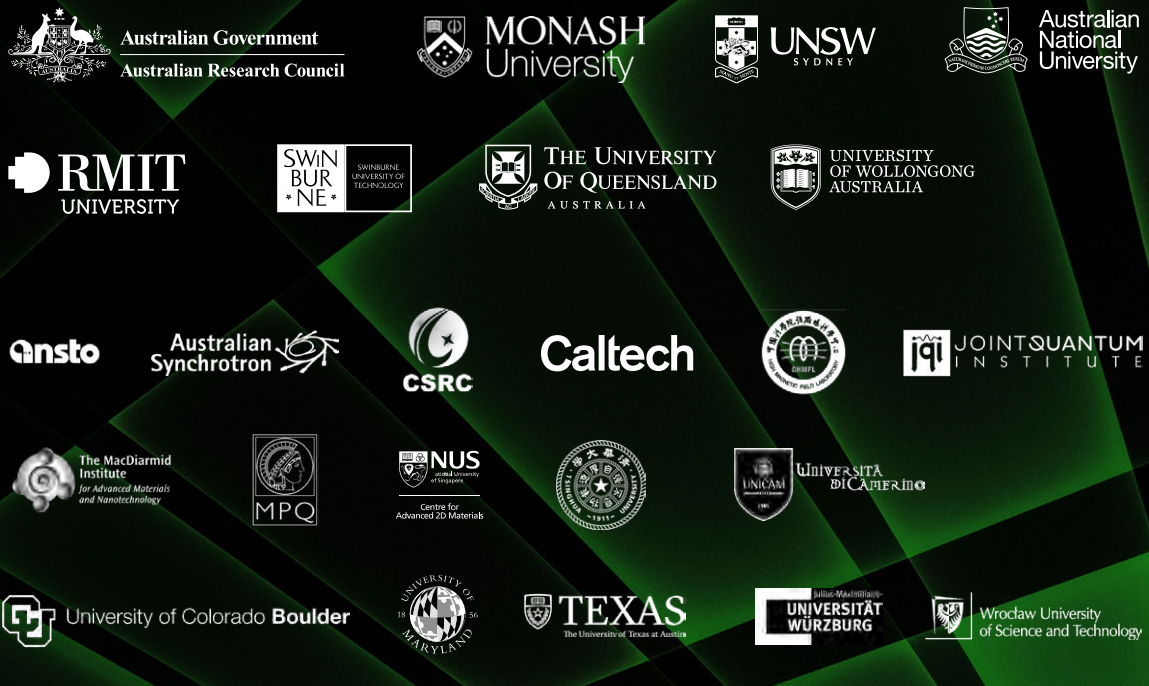

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ARC CENTRE OF EXCELLENCE IN FUTURE LOW-ENERGY ELECTRONICS TECHNOLOGIES

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