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(STANDARD PROPOSAL)

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Name & Title:	Professor Jonathan Scott
Full Address:	Department of Engineering, The University of Waikato Private Bag 3105, Hamilton, 3240

Standard proposal	Application Number: 07-UOW-004	Panel(s) PSE

From: Administration Officer
Marsden Fund
The Royal Society of NZ
PO Box 598
WELLINGTON 6140

Standard Proposal	Contact PI's surname Scott	Initials J.B.	Application Number 07-UOW-004	Panel PSE

MARSDEN FUND FULL RESEARCH PROPOSAL (STANDARD)

1. TITLE OF RESEARCH PROPOSAL

Unconventional Wide-Bandgap Circuits

2. IDENTIFICATION

Contact Principal Investigator

Name (with title):	Prof. Jonathan Scott
Full Address:	Department of Engineering, The University of Waikato Private Bag 3105, Hamilton, 3240
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Other Principal Investigator(s)

Name (with title):	Institution	Country
None		

Associate Investigator(s)

Name (with title):	Institution	Country
Mr Andrew Teetzel	Moxieworks	US/NZ

3. SUMMARY

Describe in up to 200 words the nature of your proposed research in plain English for a general audience. This summary should be able to be used for publicity purposes if the proposal is offered funding.

This project will investigate some very novel applications of microwave integrated circuits fabricated in the Gallium Nitride (GaN) wide-bandgap material system. GaN is the material system that has given us blue and white LEDs that will enable the next generation of DVDs, illuminate flat-panel displays, and replace incandescent lamps in vehicles. However, GaN also promises transistors with order-of-magnitude higher power-bandwidth product than has been possible to date. This may be the most revolutionary advance in electronics since the scaling of silicon transistors in Very Large Scale ICs brought us electronic wristwatches and personal computers. Some applications are obvious, but we feel that there are opportunities that reflect the revolutionary nature and magnitude of the technology and that have yet to be investigated. Examples include monolithic power conversion, precision diathermy, and vacuum-tube replacement. We plan to use the "fabless design" model to prototype GaN circuits because this is both the way of the future in global electronic engineering, and because this model suits small countries such as New Zealand.

4. BACKGROUND

Using only this page, give a context for the proposal by summarising in plain English the state of knowledge in the field. Instructions may be removed.

This project is very timely[1]–[3],[7]. The volume of publications on Field-Effect Transistors in the Gallium-Nitride system (GaN FETs) has increased dramatically since the turn of the millennium, yet much remains speculative with regard to applications[8]. Large R&D concerns (University of California, Northrup Grumman, Rockwell Science, Triquint, etc.) concentrate on applications of GaN in mobile communications and radar, to the exclusion of both niche markets, and markets with no existing semiconductor penetration.[4, 5, 7] Their approach is understandable, since these areas have a demonstrated need for the capability of GaN, and offer good probability of providing prompt return on investments in GaN technology.

Only discrete GaN FETs have previously been commercially available. Foundry access to Field-Effect Transistors (FETs) made in the Gallium-Nitride (GaN) system and incorporated into Monolithic Microwave Integrated Circuits (MMICs) will become commercially available circa 2008, and is already available to contributing researchers. Much of this availability is a result of a set of DARPA (Defense Advanced Research Program Agency) contracts let in 2005, and competitive response in Europe and Japan to that investment. The DARPA contracts aim "to transition gallium nitride technology from development to production", as previously happened with Gallium Arsenide (GaAs) and Indium Phosphide (InP) technologies. These DARPA contracts end in 2008, and some carry a requirement that foundry services be offered to enable industry to benefit.

Modeling of transistors to enable the simulation of circuits prior to fabrication is a critical step in the progress of a new semiconductor technology. The availability of CAD models signals the readiness of a technology for practical application. Typically equivalent-circuit models appear, followed by large-signal models of increasing sophistication. In the case of GaN transistors, both small-signal equivalent circuit models[9] and initial large-signal models including dispersion effects[10] have appeared in the literature.

Wide-bandgap semiconductor active devices in the Gallium-Nitride material system have three acknowledged advantages over Silicon and III-V technologies: (1) They have 10 times higher a power-bandwidth than even Indium-Phosphide; (2) they have intrinsic high-voltage capability; and (3) they can operate at higher temperatures and in harsh environments. Each of these properties opens up opportunities previously denied to silicon- or III-V-based technologies. We plan to take advantage of one or more of these in each of our investigations.

5. OVERALL AIM OF THE RESEARCH

Using only this page, state the general goals and specific objectives of the research proposal. Emphasise how the research will advance knowledge and increase understanding. Instructions may be removed.

The overall aims of the research are:

- To show that Gallium-Nitride MMIC technology can be practically exploited using the fabless design model, specifically in New Zealand;
- To estimate the applicability of GaN MMICs to application areas that have yet to be associated in any literature with this technology, including but not limited to:
  - Monolithic power conversion,
  - Precision medical diathermy/ablation, and
  - Vacuum-tube replacement;
- In at least one case, to complete the design and fabrication of a GaN IC and demonstrate feasibility of using that IC in an identified novel application;
- To promote the use of GaN circuits in identified novel applications through publication and by making prototype circuits and design expertise available in the relevant field;
- To train postgraduate (Masters and PhD) and undergraduate (Bachelor of Electronic Engineering) students in IC design in wide-bandgap material;
- In synergy with other projects, to build-up expertise within the IC design group at the University of Waikato in the design of wide-bandgap circuits and MMICs in particular, and to disseminate that expertise within New Zealand.

Specifically we intend:

- To put a wide-bandgap design kit in place to allow MMIC circuit design in our CAD tools;
- To design and simulate circuits in the identified application areas, and to publish these designs;
- To fabricate circuits with a GaN foundry on a "pizza" basis to allow simultaneous pursuit of different experiments;
- To characterise and test fabricated circuits, and to publish results to
  - verify the design kit,
  - where possible demonstrate the application, or
  - where appropriate explain the inapplicability of GaN to the application.

We believe that the above program will facilitate wide-bandgap design at other institutions, encourage researchers to use wide-bandgap ICs to address problems in a variety of fields, and help build a critical mass of high-frequency designers in New Zealand with a good probability of stimulating commercial activity.

6. PROPOSED RESEARCH

This section should cover where appropriate the hypotheses being tested, the methodology to be used, sampling design, and methods of data analysis. Please ensure that your description covers the entire research programme, including contributions by collaborators and postgraduate students (if any). Please use a MAXIMUM of 3 pages. This should cover the **initial** period of funding that is being sought. Instructions may be removed.

The work can be conceptually divided into stages. These are adaptions of the usual stages employed by all institutions undertaking fabless design programs in compound semiconductor systems.

The first stage involves the installation of a "design kit" for the selected GaN foundry in the selected CAD package. At time of writing, the PI's department expects to use Mentor CAD tools, but other grants and business developments may result in the availability of additional tools, such as Agilent's ADS or AWR's Microwave Office. We have opened discussion with several potential foundries, including MicroGaN in Ulm, Germany, Rockwell Science in California, and Agilent Technologies in California. The current favourite is MicroGaN, whose facilities in Ulm we have visited and who have expressed interest in collaborating with us. The crafting of the design kit will adapt our tools to provide the layers and abide by the design rules pertinent to the selected foundry. While it would be desirable for students to be involved in this, one must realistically expect a delay between the commencement of the program and the arrival of students, so this may be carried out by the PI, AI or staff as available.

The second stage is to exercise the fabrication pathway and fit models for FETs and passives. Initially one lays out a series of components and test structures; then the steps to send information to the foundry are carried through. In particular, we would include discrete active devices in a suitable probing arrangement with a defined manifold, calibration standards in identical minifolds for use with a VNA, inductors and transmission lines, etc. Once these are returned from the foundry, they are characterised in the laboratory, and model parameters are found to properly fit device models in the simulator. Laboratory measurement will be carried out using equipment at the University of Waikato, Macquarie University, and Agilent Technologies (who have expressed a willingness to become involved once we are under way). Suitable device models are available in the literature, and we hope to be collaborating with Macquarie University on a project to specifically and more accurately model GaN FETs. In any case, we expect to be able to share laboratory facilities as described above, irrespective of the progress of other projects currently proposed.

The third stage is circuit design. The plan is to attack a variety of circuits in parallel. The PI and the AI will contribute at this stage, but we hope to have postgraduate students involved. We would offer Masters and PhD candidates the chance to investigate some applications. We can identify several threads up front, each of which might be followed by one or more different people, and each of which promises to open up one or two application areas. These are:

1. *Oscillator design with a view to both medical diathermy and low phase-noise sources.* While different, there is much design synergy between these two oscillator-based applications.

   The vision for GaN-based diathermy tools is to replace the current "microwave antenna on a length of thin coax" [20, 21] with a monolothic dc-microwave oscillator based on a GaN MMIC. The high-voltage capability will mean modest supply current, and only a low-fidelity oscillator will be required. The power will be supplied to the probe tip at dc, giving low loss, low cost, and fine mechanical form. Freed from the need to deliver power through coax, the RF energy can be delivered at high gigahertz frequencies, giving highly localised heating.

   The vision for low phase-noise oscillators rests on the expectation that the high-voltage, low-noise capability of GaN will give it a wider dynamic range than any previous solid-state technology.[11, 14, 8] The low phase-noise oscillators will differ from the oscillators with diathermy application in needing a high-Q resonator. High-voltage dielectric resonators are available.[23]

2. *Monolithic switchmode power conversion.*

   Our vision for GaN-based switchmode systems is to integrate the entire converter in an IC using GaN to implement converters at GHz frequencies.[17, 18] We would initially design conventional switchmode buck converters, and advance to monolithic and resonant designs as experience grows and provided the foundry passives permit. The last 20 years has seen SwitchMode Power Supplies (SMPS) shrink in cost and size as operating frequency increased. However, there has never been a demonstration of *wholly monolithic SMPS*, since silicon and GaAs MMICs cannot offer the breakdown voltages simultaneously with fast enough transistors—they have too low a power-bandwidth product. We would hope to have circuits sufficient for converters operating between 42V and 12V. This range, for example, will be in great demand once domestic automobiles convert to the new standard of 42V, and a need for systems operating at these levels becomes widespread.

   We see this as both a harder application to demonstrate, but one with greater commercial potential. We would like to have a top-quality PhD student addressing this task over a period of years.

3. *Vacuum-tube replacement.* To the amazement of electronic engineers, vacuum tubes continue to be used in three areas today: In high-power microwave amplification in the form of travelling-wave tubes (TWTs), chiefly for satellite application; in very-high power amplification for terrestrial short- and medium-wave long-range transmission; and in high-end sound-studio equipment. GaN has been identified as the likely technology to displace TWTs, and more than one commercial concern has started work on GaN-based, solid-state, travelling-wave, amplifier MMICs. However, using GaN's wide dynamic range to displace vacuum-tubes from the audio sphere has far lower financial incentive, and faces the perception that much vacuum-tube appeal has nothing to do with the electronic performance so much as the history.

   We have good scientific reason to expect that the high-voltage capability of GaN combined with its noise performance will give it a wider dynamic range than any previous solid-state technology.[11, 14, 8] This is the property of vacuum-tubes that has sustained their use in some applications such as microphone preamplification.[13] We intend to construct simple circuits analogous to the vacuum-tube versions whose dynamic range is crucial, and empirically compare performance. The PI has particular experience in this area.

   Some might deem it frivolous to invest such effort in "valve amplifiers". This criticism has some validity. Nevertheless the demonstration will serve to verify an ability of GaN that may have crucial application elsewhere. It also tackles a debate that remains unresolved, and that contributes to the "amazement" of engineers and the popular press over the use of vacuum tubes, and has done so for some decades.

4. *Linear amplifiers.* Debate continues around the question of whether GaN FETs will enable the construction of amplifiers that are intrinsically more linear for a given power-added efficiency (PAE) than silicon. It is acknowledged that silicon, in the form of LDMOS devices, will not be able to provide the required power-distortion performance in base station amplifiers for cellular systems employing complex-modulation schemes, once user frequencies pass the current 2.5GHz standard. GaN is recognised as a contender for the

job, based on its higher operating voltages that imply reduced matching complexity in the power regime in question (tens to hundreds of Watts).

Our speculation is that GaN may be able to offer intrinsically lower distortion than previous technologies, purely through a shift to higher voltages (thus lower currents) and improved thermal properties of substrates. If so, this would suggest that GaN circuits might offer advantages in the regime curently satisfied by silicon, even below 2GHz. Resources permitting, we would like to launch an investigation into the contribution of the various mechanisms to any advantages that GaN offers. The fundamental understanding of the design constraints on power-amplifier distortion in relation to the device characteristics would help designers to assess GaN as an alternative. The field is a speciality of the PI, and a subject of special interest to Macquarie University collaborators.

We might reasonably expect to follow one or two designs from initial investigation all the way to completion and test of an Application-Specific Integrated Circuit (ASIC). Some ideas will likely prove unfeasible at the simulation stage, or available manpower will limit the number of threads that can be followed through. (Note our concerns expressed in section 11; note also in the FTE table of section 16 that we have capacity to employ more students than we will have stipends to offer. We hope to attract students with their own funding.)

The conclusion of each design thread should be publication of what amounts to a feasibility report. Given the MMIC nature and the use of compound-semiconductor monolithic circuits, we would anticipate conference publications at such venues as the CSIC (Compound Semiconductor IC Symposium), MTT-IMS (IEEE MTT Society's International Microwave Symposium), or EuMC (European Microwave Conference), with full papers appearing in an appropriate IEEE journal, such as MTT Transactions.

6a. PROPOSED RESEARCH FOR EXTENDED PERIOD (OPTIONAL)

If the applicant wishes the proposal to be considered for funding for an additional one or two years after the initial period, please indicate briefly how the research programme might be extended, and how long for. It is acknowledged that this may change as the research progresses. PLEASE USE A MAXIMUM OF HALF A PAGE.

Should one novel-application thread demonstrate feasibility and promise performance superior to existing circuits, it should be followed up. One further year's work, concentrated on such a single thread, could be expected to produce a prototype ready to be turned over to industry or to attract FRST funding.

7. FTE REQUESTS

This section should include i) the roles of all personnel, and ii) justification of any FTE requests, for the proposed research for the initial period of funding sought. PLEASE USE A MAXIMUM OF HALF A PAGE.

The AI will install the design kit, advise (postgraduate) circuit designers, carry out circuit design and simulation, supervise tapeouts, and assist in laboratory work.

Postgraduate students (ideally 2 at Masters and 2 at PhD level) will work on devising, fitting and refining active and passive device models, and carry out circuit design, layout, and simulation.

The PI will manage the project, interface with foundries, facilitate the CAD tools, supervise postgraduates, oversee wafer and device characterisation in laboratories, and carry out some circuit design and simulation if required and possible.

We request 0.4 FTE of the AI in the first year but decreasing as the project gets under way; 0.05 FTE for each of two technicians; stipends for one 3-year (PhD) and one 1-year (Masters) postgraduate; 0.2 FTE of the contact PI.

8. REFERENCES

Please list references for Sections 4-6. Use a **maximum** of 2 pages. Please include full titles.

[1] *Compound Semiconductor*, vol. 12, no. 6, July 2006.
[Special issue on GaN Electronics and the wide-bandgap sector.]

[2] Report on Australian Startup "BluGlass", *Compound Semiconductor*, vol. 12, no. 10, November 2006, pp12–13.

[3] "UK Defence Chiefs Feel the Need for GaN", *Compound Semiconductor*, vol. 12, no. 10, November 2006, p5.

[4] R. J. Trew, "Wide bandgap transistor amplifiers for improved performance microwave power and radar applications", *15th International Conference on Microwaves, Radar and Wireless Communications*, MIKON-2004, Volume 1, 17–19 May 2004, pp18–23.

[5] T. Kikkawa, "Recent progress and future prospects of GaN HEMTs for base-station applications", *IEEE Compound Semiconductor Integrated Circuit Symposium*, 24–27 October 2004, pp17–20.

[6] R.T. Kemerley, H.B. Wallace and M.N. Yoder, "Impact of wide bandgap microwave devices on DoD systems", *Proceedings of the IEEE* Volume 90, no. 6, June 2002, pp1059–1064.

[7] U. K. Mishra, P. Parikh, and Yi-Feng Wu, "AlGaN/GaN HEMTs-an overview of device operation and applications", *Proceedings of the IEEE* Volume 90, no. 6, June 2002, pp1022–1031. [This issue concentrated on wide-bandgap technology.]

[8] U. K. Mishra, "Gallium nitride electronics: Watt is the limit? [summary of GaN semiconductor devices]", *Digest of the 62nd Device Research Conference*, 21–23 June, 2004, Vol 1, pp3–5.

[9] G. Crupi, D. Xiao, D.M.M.-P. Schreurs, E. Limiti, A. Caddemi, W. De Raedt, and M. Germain, "Accurate Multibias Equivalent-Circuit Extraction for GaN HEMTs", *IEEE Transactions on Microwave Theory and Techniques*, Volume 54, no. 10, Oct 2006, pp3616–3622.

[10] A. Jarndal, B. Bunz, and G. Kompa, "Accurate Large-Signal Modeling of AlGaN-GaN HEMT Including Trapping and Self-Heating Induced Dispersion", *2006 IEEE International Symposium on Power Semiconductor Devices and ICs*, 4–8 June 2006, pp1–4.

[11] Sungjae Lee, K. J. Webb, V. Tilak, and L. F. Eastman, "Intrinsic noise equivalent-circuit parameters for AlGaN/GaN HEMTs", *IEEE Transactions on Microwave Theory and Techniques*, Volume 51, no. 5, May 2003, pp1567–1577.

[12] Sungjae Lee and K. J. Webb, "The influence of transistor nonlinearities on noise properties", *IEEE Transactions on Microwave Theory and Techniques*, Volume 53, no. 4, April 2005, pp1314–1321.

[13] Sony C800GPAC Studio Tube Condenser Microphone Product information:
`http://bssc.sel.sony.com/BroadcastandBusiness/DisplayModel?id=24120`

[14] C. Fazi and P. G. Neudeck, "Wide dynamic range RF mixers using wide-bandgap semiconductors", *IEEE MTT-S International Microwave Symposium Digest*, Colorado, 8–13 June 1997, vol. 1, pp49–51.

[15] R. J. Trew, "SiC and GaN transistors - is there one winner for microwave power applications?", *Proceedings of the IEEE* Volume 90, no. 6, June 2002, pp1032–1047.

[16] S.C. Binari, P.B. Klein, and T.E. Kazior, "Trapping effects in wide-bandgap microwave FETs", *2002 IEEE MTT-S International Microwave Symposium Digest*, Vol. 3, 2–7 June 2002, pp1823–1826.

[17] M.K. Kazimierczuk, and J. Jozwik, "DC/DC converter with class E zero-voltage-switching inverter andclass E zero-current-switching rectifier", *IEEE Transactions on Circuits and Systems*, Volume 36, no. 11, Nov 1989, pp1485–1488.

[18] Hiroyuki Hase, Hiroo Sekiya, Jianming Lu, and Takashi Yahagi, "Resonant DC–DC Converter with Class-E Oscillator", *IEEE Transactions on Circuits and Systems—I: Regular Papers*, vol. 53, no. 9, September 2006, pp2025–2035.

[19] R.D. Nevels, G.D. Arndt, G.W. Raffoul, J.R. Carl, and A. Pacifico, "Microwave catheter design", *IEEE Transactions on Biomedical Engineering*, Volume 45, no. 7, July 1998, pp885–890.

[20] I. Longo, G.B. Gentili, M. Cerretelli, and N. Tosoratti, "A coaxial antenna with miniaturized choke for minimally invasive interstitial heating", *IEEE Transactions on Biomedical Engineering*, Volume 50, no. 1, Jan 2003, pp82–88.

[21] Heng-Mao Chiu, A.S. Mohan, A.R. Weily, D.J.R. Guy, and D.L. Ross, "Analysis of a novel expanded tip wire (ETW) antenna for microwave ablation of cardiac arrhythmias", *IEEE Transactions on Biomedical Engineering*, Volume 50, no. 7, July 2003, pp890–899.

[22] James C. Lin, "Microwave Surgery Inside the Heart", *IEEE Microwave Magazine*, Volume 7, number 6, June 2006, pp32–36.

[23] Wang Li-li, Ke Xi-zheng, and Xi Xiao-li, "Technique allows simple design of microwave DROs", *IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications*, Volume 2, 8–12 Aug 2005, pp944–948.

9. TIMETABLE

Initial Number of Years (maximum of 3): **3**

Describe in general terms the advances you hope to make in each year for the **initial** period of funding sought. Please restrict comments to the **initial** period of funding only. It is acknowledged that this timetable may be revised as the research progresses.

In general terms, we hope to maintain a schedule of two "tape-outs" per year, with the first 6–9 months set aside for tool and model calibration.

In Year 1:

- Select a foundry, select the CAD program, and enter the design kit;
- Lay out test structures, cal standards, passives, test devices, and "tape out" the first mask set;
- Recruit postgraduate student(s);
- Characterise devices and refine models;
- Carry out initial design of one or more circuits;
- "Tape out" the second mask set (first masks containing circuits).

In Year 2:

- Add postgraduate students to the design team;
- Test circuits from mask set 2;
- Refine previous and start new designs;
- Tape out mask sets;
- Make noise and dynamic range measurements;
- Prepare conference reports on circuits.

In Year 3:

- Refine previous and start new designs;
- Tape out and test mask sets;
- Prepare manuscripts.

10. SPECIAL REQUIREMENTS

Describe any special requirements for equipment or resources (e.g., mass spectrometers, laboratories, research ships) and indicate how these will be met. You must demonstrate that you will have the means to complete the research.

Our major cost will be foundry wafer fabrication. This is obviously crucial and central to the work. The estimated cost per fab run is NZ$47,800 at current exchange rates (say $48k). We would like to have two fabrication runs per year. We hope to share costs with collaborators at Macquarie University who will be working on "conventional" circuits in the same wide-bandgap material system.

The Associate Investigator (Teetzel) has retired and intends to live in New Zealand. We hope to draw on his expertise, on a part-time basis. The salary/FTE request is literally to pay for his time on site, and should not be considered in the same sense as requests for UoW staff time.

We request funds to partially cover cost of travel to (1) collaborators' laboratories whose equipment and expertise we will share, (2) the GaN foundry whose process we will use, (3) US corporate and NZ university sites to access specialised equipment such as wire bonders and nonlinear vector network analysers, and (4) conferences. (The cost of complementary visits are requested in the collaborator's grant budgets.)

11. SPECIAL SKILLS

The skills of the Principal and Associate Investigators and other named researchers are included in Section 15. If other staff, particularly postdoctoral researchers or others providing specialist services, are included in the proposal, indicate here what skills are available or are being sought.

It is acknowledged that postgraduate candidates with the skills to carry out high-frequency design and integrated circuit design are scarce. One typically seeks candidates familiar with one or more of the following: Analog filters, transmission lines, Smith Charts, S-parameters, tuned amplifiers, and impedance matching. We see postgraduate recruitment as a major hurdle. We feel that there will be a significant financial cost and risk of delay associated with attracting suitable candidates.

11a. DEVELOPMENT OF RESEARCH SKILLS

Please explain briefly how the intended research programme would contribute to the development or broadening of research skills in New Zealand.

This project will allow a New Zealand university to be a pioneer in the latest rising compound semiconductor technology, Gallium-Nitride. It will demonstrate to the local research community the accessibility and value of compound semiconductor IC design. It will help UoW's Engineering department to build a core research group employing the IC foundry model. It will train postgraduates in the techniques of IC design, practiced "at a distance" from the foundry. It will bolster domestic expertise in high-frequency electronics.

The following background helps to understand the value of these aims: Throughout previous decades, integrated circuit design required that the designer's host institution own and run a semiconductor fab facility, or have a close working relationship with someone who did. This changed in the 1990s with the worldwide trend towards "fabless design houses" and "semiconductor foundries", leading to the the so-called "foundry model". This business model is epitomised by foundries such as TSMC in Silicon and WinSemi in III-V materials, and Australian-R&D companies such as G2 Microsystems (Silicon VLSI) and Mimix Broadband (III-V MMICs). A similar situation will follow in wide-bandgap, starting with GaN. It is now possible to design and make ICs on a relatively modest budget, from almost anywhere in the world. This trend suits small countries such as New Zealand that cannot justify the high cost of fabrication facilities. The PI and the AI previously worked with a "captive fab" in a US company that wholly owned more than one fab line, and we look forward to moving to the fabless design model that is appropriate to New Zealand.

12. ETHICAL OR REGULATORY OBLIGATIONS

It is your responsibility to ensure that all ethical or regulatory obligations are met (e.g. from ERMA, MAF, Animal Ethics, Human Ethics). Indicate what steps have been, or will be, taken to obtain the necessary approvals. Full documentation needs to be received before any grant is paid.

No ethical approvals required.

13. MAORI RESPONSIVENESS

If your research is of relevance for Maori, there is an expectation that appropriate consultation with Maori be undertaken. Please provide a brief summary of the consultation process so far and plans for ongoing consultation. Maori applicants undertaking Maori research should demonstrate their linkages and what processes they have used in developing and designing their proposal. Please refer to the relevant sections in the *2007 Full Research Proposal Guidelines for Applicants.* If no specific interest for Maori can be identified, this section should be left blank.

None.

14. CONTACT DETAILS OF OTHER INVESTIGATORS

Principal Investigator(s) other than Contact Principal Investigator

None.

Associate Investigator(s)

Name (with title):	Mr Andrew Teetzel	
Full Address:	P.O. Box 1301 6755 West Trail Creek Road Wilson, WY 83014 (Approved to immigrate to NZ in 2007.)	
Telephone:	+1(307) 734-0125	
Fax:	—	
Email:	andyt_83014@yahoo.com	

Other Collaborators

Name (with title):	Professor Anthony Parker	
Full Address:	Department of Electronics Building E6A, Room 247 Macquarie University Sydney, AUSTRLAIA 2109	
Telephone:	+61(2)9850-9131	
Fax:	+61(2)9850-9128	
Email:	tonyp@ics.mq.edu.au	
CV & details:	http://www.ics.mq.edu.au/∼tonyp/	

15. CURRICULUM VITAE, PUBLICATIONS AND OTHER PUBLISHED WORKS

Use copies of Sections 8a and 8b from your Preliminary Research Proposal, renumbering as section 15, and updating if necessary. Please use only one page per person for a CV. For Principal Investigators, publications should be a maximum of **3 pages in total**. For Associate Investigators, there is a limit of **1 page** for publications; please indicate best or most relevant publications if the list extends beyond this. Please bold the applicant's name in lists of authors. The information needs to be supplied for each named research person (other than research/technical assistants). This includes postdoctoral fellows if a person has already been chosen for the position. Ensure that Section 15A is followed by 15B for the contact PI first, then include Sections 15A and 15B for the next named research person, and so on.

Name of researcher:	Jonathan B Scott

Tertiary Education:	BSc., 1977, The University of Sydney
	B.E. (hons), 1979, The University of Sydney
	M.Eng.Sc., 1985, The University of Sydney
	PhD, 1997, The University of Sydney
Distinctions/Honours:	Senior Member, IEEE
	Member, AES
	FIEAUST
	British Telecom Fellowship, 1993
	Professorial Fellow, Macquarie University, Sydney
Employment Record:	July 2006, Foundation Professor of EE, Uni of Waikato
	1998–2006, Manager, Advanced Measurements Lab, HP/Agilent, CA
	1997–1998, Chief Engineer, RF Technology, Sydney
	1988–1997, Senior Lecturer, The University of Sydney
	1985–1988, Director, Brereton Samuel Research
	1980–1982, Electronic Designer, Modern Magazines
Other Information:	Macquarie University Innovation Prize, 2005
	NB: My most influential work in the period 2000–2005 remains confidential to my previous employer, Hewlett-Packard/Agilent Technologies. This work involves the design of MMICs through the Santa Rosa site captive compound semiconductor fabrication facility.
	A full and laborious CV, still exclusive of my MMIC work, is available at: http://www.scottpages.net/CurriculumVitae.html.

Professor Scott has maintained a life-long interest in radio and high-frequency electronics. He started as an Amateur Radio Operator while still at high school, eventually taking an Electronics major in Electrical Engineering with a thesis in antennas. He worked as an electronics journalist, and then with the Air Navigation Group involved with high-frequency signal analysis and antennas. He taught electronics, and wrote and taught a High-frequency Electronics course. His designs operate from high-frequency ultrasound at a few MHz to millimetre-wave signals in excess of 100GHz. He also maintains interests in electric traction, audio systems, device physics and compact modeling.

Publications (2002 - present)

Indicate **total** number of a) books, b) refereed journal articles or c) refereed conference papers published (including before 2002)	(a)	(b)	(c)
	3	23	50

(Category f) Patents granted:

"Method and Apparatus for Calibrating a Sampling Circuit", US Patent 6,795,787, granted 21 September 2004. **Jonathan B Scott** sole named inventor.

"Scattering-Parameter Travelling-Wave Magnitude Calibration System and Method", US Patent 6,982,561, granted January 3, 2006 **Jonathan B Scott** sole named inventor.

(Category f) Patents filed and pending:

"Method To Eliminate Low Frequency Oscillations (lfos) In III-V Compound Semiconductor Bipolar Transistors (hbts)", filed March 2005. Inventors: Masaya Iwamoto, **Jonathan B Scott** and Tom Low.

"Balance Method in Thermocouple RF Power Measurement", filed January 31, 2006. **Jonathan B Scott** sole named inventor.

"Load Resistor Aging Sense for RF Power Meters", filed January 31, 2006. **Jonathan B Scott** sole named inventor.

"Pulse Generator", filed May 2006. Inventors: **Jonathan B Scott** and Daniel Gunyan

"RF Power Sensor", filed May 2006. **Jonathan B Scott** sole named inventor.

"Fast Extrapolation of a Thermal Sensor's Final Value and Discovery/Verification of a Thermal Sensor's Thermal Time Constant", filed October, 2006. **Jonathan B Scott** sole named inventor.

(Category a) Journal papers:

Peter S. Blockley, **Jonathan B Scott**, Daniel Gunyan, and Anthony E Parker,
"Noise Considerations When Determining Phase of Large-Signal Microwave Measurements",
IEEE Transactions on Microwave Theory and Techniques,
vol. 54, no. 8, August 2006, pp3182–3190.

Jonathan B Scott,
"Investigation of a Method to Improve VNA Calibration in Planar Dispersive Media Through Adding an Asymmetrical Reciprocal Device",
IEEE transactions on Microwave Theory and Techniques,
vol. 53, no. 9, September 2005, pp3007–3013.

Jonathan B Scott,
"New Method to Measure Emitter Resistance of Heterojunction Bipolar Transistors",
IEEE Transactions on Electron Devices,
vol. 50, No. 9, September 2003, pp1970–1973.

Jonathan Scott, Jan Verspecht, Babak Behnia, Marc Vanden Bossche, Alex Cognata, Frans Verbeyst, Mark Thorn, and Daniel R. Scherrer,
"Enhanced On-wafer Time-Domain Waveform Measurement through Removal of Interconnect Dispersion and Measurement Instrument Jitter",
IEEE transactions on Microwave Theory and Techniques,
vol. 50, no. 12, December 2002, pp3022–3028.

(Category e) Refereed conference papers:

Peter S. Blockley, **Jonathan B Scott**, Daniel Gunyan and Anthony E Parker,
"Nonlinear Network Analysis and Measurement", Workshop on Applications in Radio Science, (Phil Wilkinson, Ed.), Leura, NSW, Australia, 15-17 Feb. 2006, Union Radio Science International, Commission B, National Committee for Radio Science.

Jonathan B Scott,
"Pulsed-I/V and Pulsed-S- Parameters: Some Applications", Pulsed I/V Measurement Workshop, 64th ARFTG Microwave Measurement Conference, Orlando, Dec 1-3, 2004.

Jonathan B Scott,
"Rapid Millimetre-wave Sampler Response Characterization to Well Beyond 120GHz Using an Improved Nose-to-nose Method", paper TH3A-3, MTT-s IMS Digest, Philadelphia, June 2003, pp1511–1514.

Masaya Iwamoto, David E.Root, **Jonathan B Scott**, Alex Cognata, Peter M. Asbeck, Brian Hughes, and Don C. D'Avanzo,
"Large-Signal HBT Model with Improved Collector Transit Time Formulation for GaAs and InP Technologies", IMS Digest, MTT-S IMS 2003, paper WE1A-1, Philadelphia, pp635–638.

Masaya Iwamoto, Craig P.Hutchinson, **Jonathan B Scott**, Thomas S.Low, Mani Vaidyanathan, Peter M.Asbeck, and Don C.D 'Avanzo,
"Optimum Bias Conditions for Linear Broadband InGaP/GaAs HBT Power Amplifiers", IMS Digest, MTT-S IMS 2002, pp901–904, paper WE3A-2, Seattle.

Jonathan Scott, Babak Behnia, Marc Vanden Bossche, Alex Cognata, Jan Verspecht, Frans Verbeyst, Mark Thorn, and Daniel R.Scherrer,
"Removal of Cable and Connector Dispersion in Time-Domain Waveform Measurements on 40Gb Integrated Circuits", IMS Digest, MTT-S IMS 2002, pp1669–1672, paper TH2E-4, Seattle.

David G. Haigh, Danny R. Webster, Reza Ataei, Tony E. Parker and **Jonathan B Scott**,
"Issues in Nonlinear Circuit Theory and Application to High Frequency Linear Amplifier Design" Proceedings of the Nonlinear Dynamics of Electronic Systems Conference, Delft, 21–23 June 2001, Invited Presentation no. 1.

Jonathan B Scott,
"Nonlinear III-V HBT Compact Models: Do We Have What We Need?", IEEE MTT-S International Symposium Digest, Phoenix, June 2001.

Jonathan B Scott,
"Reconciliation of Methods for Bipolar Transistor Thermal Resistance Extraction", IEEE International Symposium on Circuits and Systems, Sydney, May 2001.

Jonathan B Scott,
"Measuring and characterizing devices: Tutorial Guide", The IEEE International Symposium on ISCAS, 6-9 May 2001, Pages: 2.1_1-2.1_15.

(ii) **Prior publications relevant to this proposal**

(Category e) Refereed conference papers:

Jonathan Scott and Tom Low,
"Avalanche Breakdown in HBTs: Variation with Collector Current and Effect on Linearity", 2000 GaAs IC Symposium, November 2000.

Name of researcher:	Andrew M Teetzel

Education: Purdue University, BSEE with distinction, 1979
University of Illinois, MSEE 1984
Ongoing SITN and NTU classes
Regular ISSCC attendee

Employment: **Agilent Technologies / Hewlett-Packard Company 1984–2006**
Designed the first GaAs MMIC ever commercially shipped. Responsibilities included circuit design, customer colloboration, test development, applications engineering, market surveys, and product engineering.

- 1st GaAs IC to ship in HP instrument, 1985
- 2-6 GHz medium power amplifier
- 2-7 GHz LO distribution amplifier
- High power amplifier within YIG magnetic structure
- Broadband IQ modulators covering 0.25-4 GHz, 0.25-12 GHz, and 3-20 GHz
- 90 dB SNR continuous-time bandpass delta-sigma ADC
- hybrid microcircuits integrating mechanical packaging, thinfilms, plus ICs.
- Variable frequency ring oscillator with operation above F_t.

Mead Microelectronics (http://www.mead.ch) Corvalis, OR 1999–Present
Lecturer, Advanced Engineering Course "RFIC Design", Oct. & Nov.

Hewlett-Packard Company Loveland, CO 1979–1981
Designed high speed ECL-based timing circuitry for ATE systems.

(i) **Publications (2002 - present)**

Indicate **total** number of a) books, b) refereed journal articles or c) refereed conference papers published (including before 2002)	(a)	(b)	(c)
	0	1	1̃2

(Category f) White Papers:

Numerous internal publications on RF, microwave, and delta-sigma topics, Hewlett-Packard Company. These remain protected by industrial secrecy obligations.

(Category f) Patents filed and pending:

Two U.S. Patents (US5694093 and US5644260) pertaining to broadband IQ modulators

(ii) **Prior publications relevant to this proposal**

(Category e) Refereed Conference proceedings:

A. **Teetzel**, "A Stable 250 to 4000 MHz GaAs IQ Modulator IC", 1997 International Solid-State Circuits Conference, Digest of Technical Papers, pp. 364–365.

A. **Teetzel** and R. Walker, "A GaAs IC broadband variable ring oscillator and arbitrary integer divider", Digest of the IEEE 1992 Microwave and Millimeter-Wave Monolithic Circuits Symposium, Albuquerque, NM.

A. **Teetzel**, "The TAMP GaAs IC Microwave Amplifier Project - A Recapitulation," IEEE 1991 GaAs IC Symposium, Monterey, CA.

A. **Teetzel**, "Efficient High Power GaAs Monolithic Amplifiers - It's a Cinch!", IEEE 1990 International Microwave Symposium, Dallas, Texas.

A. **Teetzel**, "MMIC Techniques Pump High Power", Microwaves and RF, July 1989, pp. 79–86.

Name of researcher:	Professor Anthony Parker

Tertiary Education: BSc., 1983, The University of Sydney
B.E. (hons), 1985, The University of Sydney
PhD, 1992, The University of Sydney

Distinctions/Honours: Senior Member of The IEEE
Member of The Institution of Engineers, Australia
Member of The ITEE Society
Director, CNERF

Employment Record: 1990–present, Macquarie University, Sydney
1999, Visiting Scientist, Agilent Technologies, CA
1994, Consultant, M/A-COM, MA, USA
1991, Visiting Researcher, University College, London
1984–1986, Engineer, Overseas Telecommunications Commission(Aust)
1989–1990, Professional Assistant, University of Sydney

Other Information: Macquarie University Innovation Prize, 2005

Anthony Parker started work with VHF radio and microwave systems, and satellite earth-station installations. In 1986, he began research in design techniques and circuit models for gallium arsenide microwave technology at The University of Sydney. This was in collaboration with the Division of Radiophysics of Australia's Commonwealth Scientific' and Industrial Research Organization.

He joined Macquarie University, Sydney in 1990 and is now Head of the Electronics Department. He has a continuing project on pulsed characterization of microwave devices and design of low distortion communications circuits. He has consulted with several companies including M/A-COM, MA and Agilent Technologies, CA. He has developed accurate circuit simulation techniques, such as used in FET and HEMT models. His recent work has been in the area of intermodulation in broadband circuits and systems, including a major project with Mimix Broadband, Inc.

Professor Parker has authored or co-authored over 120 publications. He is a Senior Member of the Institute of Electrical and Electronics Engineers and a member of the Institution of Telecommunications and Electronic Engineers, Australia and a committee member of the IEEE AP/MTT NSW Local Chapter. He directs the Collaborative Nonlinear Electronics Research Facility at Macquarie University.

Publications (2002 - present)

Indicate **total** number of a) books, b) refereed journal articles or c) refereed conference papers published (including before 2002)	(a)	(b)	(c)
	4	25	75

(Category a) Journal papers:

P. S. Blockley, J. B. Scott, D. Gunyan, and A. E. **Parker**, "Noise considerations when determining phase of large-signal microwave measurements," *IEEE Trans. Microwave Theory Tech.*, vol. 54, no. 8, pp. 3182–3190, Aug. 2006.

J. Brinkhoff and A. E. **Parker**, "Device characterization for distortion prediction including memory effects," *IEEE Microwave Wireless Compon. Lett.*, vol. 12, no. 3, pp. 171–173, Mar. 2005.

A. E. **Parker** and J. G. Rathmell, "Broad-band characterization of FET self-heating," *IEEE Trans. Microwave Theory Tech.*, vol. 53, no. 7, pp. 2424–2429, July 2005.

J. Brinkhoff and A. E. **Parker**, "Effect of baseband impedance on FET intermodulation," *IEEE Trans. Microwave Theory Tech.*, vol. 51, no. 3, pp. 1045–1051, Mar. 2003.

A. E. **Parker** and J. G. Rathmell, "Bias and frequency dependence of FET characteristics," *IEEE Trans. Microwave Theory Tech.*, vol. 51, no. 2, pp. 588–592, Feb. 2003.

J. Brinkhoff, A. E. **Parker**, and M. Leung, "Baseband impedance and linearization of FET circuits," *IEEE Trans. Microwave Theory Tech.*, vol. 51, no. 12, pp. 2523–2530, Dec. 2003.

A. E. **Parker** and S. Maas, "Comment on "ill conditioning in self-heating FET models" [and reply]," *IEEE Microwave Wireless Compon. Lett.*, vol. 2, no. 9, pp. 351–352, Sept. 2002.

(Category e) Refereed conference papers:

J. A. Howarth, N. Weste, L. M. Davis, J. Harrison, and A. **Parker**, "Towards a 60GHz gigabit system-on-chip," in *Proceedings 16th WWRF Meeting*, Shanghai, China, 26-28 Apr. 2006, pp. 1–8.

A. E. **Parker** and J. G. Rathmell, "Dispersion of linearity in broadband FET circuits," in *Proceedings of European Microwave Integrated Circuits Conference*, A. Gibson, Ed., The European Microwave Association. Manchester: Casusal Productions Pty Ltd Australia, 10–13 Sept. 2006, pp. 320–323.

V. Gutta, T. Fattorini, and A. E. **Parker**, "Intermodulation nulling in anti-parallel diode pair mixers," in *Asia-Pacific Microwave Conference Proceedings*, K. Araki, Ed., vol. 1, The Institute of Electrical and Electronics Engineers. Yokohama, Japan: Institute of Electronics, Information and Communication Engineers, 12–15 Dec. 2006, pp. 461–464.

J. A. Howarth, A. P. Lauterbach, M. J. Boers, L. M. Davis, A. **Parker**, J. Rathmell, M. Batty, W. Cowley, C. Burnet, L. Hall, D. Abbott, N. Weste, and J. Harrison, "60GHz radios: Enabling next-generation wireless applications," in *Proceedings IEEE Tencon*, R. Harris, Ed. Melbourne, Australia: The Institute of Electrical and Electronics Engineers Region 10, 21-24 Nov. 2005, pp. 2354–2359.

G. Qu, A. E. **Parker**, and G. Zhang, "Intrinsic dependence of intermodulation distortion in HEMTs," in *Asia-Pacific Microwave Conference Proceedings*, A. Parfitt, Ed., vol. 5. Suzhou China: The Institute of Electrical and Electronics Engineers, Inc., New York, NY, USA, 4–7 Dec. 2005, pp. 850–853.

16. FTE TABLE

List the time involvement of personnel in terms of a Full Time Equivalent (FTE). Give all names (except when they are as yet unknown for such people as postdoctoral fellows and postgraduate students). All FTEs should be included regardless of whether funding is being requested.

Name	FTE Year 1	FTE Year 2	FTE Year 3
Principal Investigator(s)			
Professor Jonathan Scott	0.2	0.2	0.2
Associate Investigator(s)			
Mr Andrew Teetzel	0.4	0.2	0.1
Postdoctoral fellow(s)			
—	—	—	—
Research/Technical Assistant(s)			
Mr Michael Cosgrove	0.05	0.05	0.05
Mr Bruce Rhodes	0.05	0.05	0.05
Others (name)			
Prof. Anthony Parker	0.05	0.05	0.05
Postgraduate student(s)			
PhD (Not Named)	1.0	1.0	1.0
Masters (Not Named)	—	1.0	—
PhD (Not Named)	1.0	1.0	1.0
Masters (Not Named)	—	—	1.0
TOTAL	2.75	3.55	3.45

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17. BUDGET (NZ $)

	Year 1		Year 2		Year 3	
	BUDGET	FTE	BUDGET	FTE	BUDGET	FTE
Salaries: (giving names) Principal Investigator(s) Professor Jonathan Scott	26,200	0.2	26,200	0.2	26,200	0.2
Associate Investigator(s) Andrew Teetzel	40,000	0.4	20,000	0.2	10,000	0.1
Postdoctoral fellow(s)						
Research/Technical Assistant(s) Bruce Rhodes Michael Cosgrove	2,750 2,750	0.05 0.05	2,750 2,750	0.05 0.05	2,750 2,750	0.05 0.05
Others (name) Anthony Parker	0.00	0.00	0.00	0.00	0.00	0.00
Salary-related costs Recruitment advertising ACC levy Superannuation	7,600 287 2,695	-	- 207 2,695	-	- 167 2,695	-
Total Salaries & Salary-related costs (a)	82,282	0.70	54,602	0.50	44,562	0.40
Other Costs: Indirect Costs: Overheads	78,870	-	56,870	-	45,870	-
Direct Costs Expendables (see section 18a)	17,203	-	21,203	-	17,203	-
Equipment depreciation/rental (specify in section 18b)	2,240	-	2,240	-	2,240	-
Postgraduate student(s) PhD MPhil	25,500	1.0	25,500 22,500	1.0 1.0	25,500	1.0
Sub-contractor(s) (specify in section 18c)						
Extraordinary expenditure Half share of foundry costs	48,000	-	48,000	-	48,000	-
Total Other Costs (b)	171,813	1.0	176,313	2.0	138,813	1.0
Sub Total (a) + (b)	254,095	1.70	230,915	2.50	183,375	1.40
GST at 12.5%	31,762	-	28,864	-	22,922	-
TOTALS	285,857	1.70	259,779	2.50	206,297	1.40

18. DIRECT COST BUDGET DETAILS

Please specify the items for the following (excluding GST). Please break down into costs per year.

a) Expendables

- Probing consumables (custom manipulator mounting hardware, coplanar microwave wafer probes, substrate material, semi-rigid cable, adapters, etc.) .... $ 3,000/pa
- Student fees .... $4,000 or 8,000/pa
- Wire bonding (transit costs and fees to connect MMICs to patterned substrates by means of ultrasonic wire bonding machine) .... $ 900/pa
- Annual IC/microwave CAD software licence (costs half shared with UoW) .. $ 1,800/pa
- Access to IEEE Explore database (not available through UoW library) .... $ 653/pa
- Travel (2/3 share of estimated cost of airfares+accomodation for 1 person travelling to Australia once/year and to either Europe or USA once/year for purposes of foundry visit and use of lab facilities, combined with conference attendance) .... $ 6,850/pa

b) Equipment depreciation/rental (if not already covered under *Indirect Costs*)

- Allow 10% usage of precision milling facility, microscopes and high-frequency measurements lab including microwave SA, VNA, etc. .... $ 2,240/pa

c) Subcontractors

- None .... $ 0.00

d) Extraordinary expenditure (describe these if not covered under special requirements, Section 10)

- Please see section 10 for more detail.
- Wafer fabrication (foundry access) .... $ 48,000/pa

19. BUDGET PRIORITIES

Please list in order of priority those items critical to the success of the proposal. For each priority, please indicate both the total cost associated with this and the cumulative cost (including previous priorities) over the course of the project. You should include any requested salaries of Principal and/or Associate Investigators.

Priority	Cost associated with priority	Cumulative cost
PI FTE	195,530	195,530
Foundry costs (UoW half share)	162,000	357,530
Probing parts & consumables	10,125	367,655
CAD Tools license (share)	6,075	373,730
PhD stipend+fees	99,563	473,292
MPhil stipend+fees (yr 2)	29,813	503,105
PG advertising (yr 1)	8,550	511,655
Collaborator site visits	2,869	514,523
Wire bonding	3,038	517,561
IEEE database access	2,204	519,765
Foundry/conference/lab travel (share)	20,250	540,015
AI salary (halves each yr)	165,375	705,390
Technical support FTE	38,981	744,371
Lab equipment depreciation	7,560	751,931

20. VARIATIONS IN FUNDING

If you are requesting multi-year funding, use this space to describe briefly the reasons for any variation in funding requirements between years. The reasons you give should be consistent with the information provided in Sections 6 & 9.

We ask for a Master of Philosophy student stipend in year 2 only.
We ask for a one-time advertising campaign to recruit PG students in year 1.
The contribution of the AI halves each year compared to the previous.

21. OTHER FUNDING

a) Indicate whether non-Marsden funding (e.g., NERF/HRC/NSOF/CoRE/TEC/Commercial/Other) has been i) received or ii) applied for, for this or a related research objective or piece of work. Include information on the FTEs applied for or received from non-Marsden government funding sources (such as NERF/HRC/CoRE).

i) Funding received

Title of application	Funding source	Investigator(s) involved (& FTE)	Relationship to current Marsden proposal
— none —	—	—	—

ii) Funding applied for

Title of application	Funding source	Investigator involved (& FTE)	Relationship to current Marsden proposal
"Future generation high-performance radio communications circuits in gallium nitride technology"	Australian Research Council (ARC)	Jonathan Scott (0.1 FTE)	This work would run in parallel, to share fabrication costs and capitalise on synergies. It involves the application of GaN circuits to conventional application areas, specifically complex-modulated radio.
GaN Power Amplifier MMIC Design (due for submission mid-2007)	High-Frequency Technology Center, Agilent Technologies	Jonathan Scott (0.1 FTE), Marcus Wilson (0.3 FTE)	Intellectual synergy but no financial overlap. Strict separation of IP to be maintained.

b) Indicate any current or previous Marsden-funding of all principal and associate investigators.

Investigator's name	Title of research programme	Role (PI or AI)	FTE	Dates of tenure
— none —	—	—	—	—

c) Indicate any periods of leave to be sought during the period of proposed Marsden funding.

No leave apart from regular annual leave.

22. DECLARATION BY DULY AUTHORISED AGENT

The Royal Society of New Zealand and the Marsden Fund Council undertake to collect, use and store the information you provide to enable your application to be evaluated. This information will not be supplied to any other organisation.

The personal information supplied in this Full Research Proposal form will be used in accordance with the principles of the Privacy Act 1993.

I acknowledge the information contained herein is accurate and can be used in the manner described.

I will indemnify the Royal Society of New Zealand and the Marsden Fund Council from any claims, demands, costs, action or proceedings of any nature which may arise at any time in relation to this application.

I confirm that the consent of each individual applicant referred to in this application has been obtained for the provision of personal information in support of this application.

I understand that individual or specific feedback to unsuccessful applicants will be available from referees' reports and panel convenors.

Name	Signature	Date
Professor Jonathan Scott Principal Investigator (Contact person)		
xxxx xxxxxx xxx xxxx xxxxxx xxx Duly authorised agent from host organisation		