**ARCS® Foundation, Inc.**
**UNIVERSITY RELATIONS APPROVAL FORM A**

*For approval of Departments/Programs including Multidisciplinary*
*Programs Within an ARCS Foundation Approved Institution*

In order to receive funding from ARCS Foundation, every department/program or multidisciplinary program is required to be approved by ARCS National through the National Board University Relations review and approval process.

- ▪ If the Department/Program or Institution housing it is ranked within the top 50 in the nation (see SUGGESTED RESOURCES FOR RANKING DEPARTMENTAL SUBMISSIONS, in the Appendix

  of this form), please complete **Section I**
- ▪ If the Department/Program or Institution housing it is **not** ranked within the top 50 in the nation (see SUGGESTED RESOURCES FOR RANKING DEPARTMENTAL SUBMISSIONS, in the Appendix of this form), please complete **Sections I and II**
- ▪ If this is a multidisciplinary program please complete the additional questions as indicated below. Please refer to the SUGGESTED RESOURCES FOR RANKING DEPARTMENTAL

  SUBMISSIONS, in the Appendix of this form, and as appropriate, please complete **Sections I and II**

This completed form, along with any attachments, must be submitted to the National VP, University Relations at least six (6) weeks prior to a National Board meeting. Incomplete forms cannot be considered.

CHAPTER: ARCS Northern California

Chapter VP, University Relations or President: Rada Brooks and Leslie Van Houten - Co VP's

University Relations

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Date Approved by Chapter Board: April 5, 2023

Date of Submission to National VP, UR: April 11, 2023

NATIONAL:

Date and Resolution by National:

## SECTION I
**Basic Information**

Name of Institution: University of California, Santa Cruz
*(Parent organization)*

Name of Division: Baskin School of Engineering
*(School, college, division, institute, if applicable)*

Name of Department/Program: Applied Mathematics
*(Indicate if multidisciplinary and explain)*

Institution Contact: Qi Gong,

Title: Professor and Department Chair

Email: qgong@ucsc.edu

Tel: 831-459-3753

## **Area of Study**

1. Specify the ARCS approved Area(s) of Study, under which this discipline falls.

Mathematics

2. If the department/program or primary area of the multidisciplinary program does not fall within our approved Areas of Study, please provide the following information:

    A. Demonstrate how it relates to the area(s).

    B. If this is an entirely new area of study confirm that the research being done in the department/program or multidisciplinary program is "hard" or "bench" science and not comparative or clinical research. Cite examples. The degree-granting department must be a "hard" science. (Refer to Appendix)

    C. Explain how this area of study supports the standards of excellence essential to the ARCS mission.

## **Overview of Department/Program or Multidisciplinary Program**
Provide an overview of the department(s)/program(s)

Applied Mathematics is a field of research specialized in the application of analytical and numerical tools and techniques towards the solution of complex quantitative problems in science and engineering. At the undergraduate level, these tools typically include advanced calculus (up to vector calculus), analysis (real and complex), linear algebra, advanced differential equations (up to dynamical systems and partial differential equations), programming, numerical analysis, and probability theory. At the graduate level and beyond, applied mathematicians will also master

additional tools, such as statistics, stochastic modeling, asymptotic methods, advanced linear algebra, high-performance computing, uncertainty quantification, optimization and many others, and will further specialize in an area of application, such as mathematical biology, mathematical geosciences, control theory, imaging sciences, financial mathematics, data science, and many others.

The Applied Mathematics Department (AM) of the Baskin School of Engineering at UC Santa Cruz was established in July 2018 as an outcome of the split of the former Department of Applied Mathematics and Statistics into two separate departments (Applied Mathematics, and Statistics). Today, the AM department consists of nine ladder-rank faculty members (Nicholas Brummell, Pascale Garaud, Marcella Gomez, Qi Gong, Abhishek Halder, Vanessa Jonsson, Dongwook Lee, Daniele Venturi, Hongyun Wang), one emeritus faculty (Marc Mangel), three adjunct faculty (Frank Giraldo and Wei Kang from the Naval Postgraduate School at Monterey, and Steven Munch from NOAA Fisheries), as well as several regular lecturers who teach courses ranging from lower to upper division undergraduate courses. Of the nine core faculty, three have been hired since 2017. Another two hires are planned for 2022/23, one on scientific machine learning, and one on computational genomics.

The AM faculty has expertise spanning a range of fields, including control and optimization (Gong, Halder, Gomez, Kang), fluid dynamics (Brummell, Garaud, Lee, Giraldo), high-performance computing (Brummell, Lee, Giraldo), uncertainty quantification (Venturi), mathematical and computational biology (Gomez, Wang, Jonsson, Mangel, Munch), stochastic modeling (Venturi, Wang). Their research has a strong focus on applications, and they collaborate broadly with colleagues in other departments at UCSC and beyond. The AM faculty has been extremely successful at securing extramural funding from various state and federal agencies, at the level of about $990,000 (including direct and indirect costs) per year in the past 5 years. This funding helps them run a thriving research program. They regularly publish in journals at the highest level in their respective fields, and their work is highly cited (the 4 most senior core faculty, Brummell, Garaud, Gong, and Wang have each been cited over 2,500 times).

The Applied Mathematics Department offers several degree programs both at the undergraduate level (B.S. and minor in Applied Mathematics), and at the graduate level (MS in Applied Mathematics, MS in Scientific Computing and Applied Mathematics, and PhD program in Applied Mathematics). As of Fall 2022, the department has 22 PhD students, 4 MS students in the Applied Mathematics program, 16 MS students in the Scientific Computing and Applied Mathematics program and approximately 70 declared undergraduate students. Students are trained in three major areas: analytical techniques for applied mathematics, scientific computing, and at least one (usually several) areas of applications, to be selected by the student based on their desired career. Many professional development workshops are offered throughout the year that help students identify potential career paths, find internships, and meet program alumni.

The BS program was launched in 2019, and as such is very young with only three alumni so far (all went on to graduate school). There are many alumni of the MS and PhD programs, by contrast, and the vast majority were able to secure the career of their choice. We help students in that process through a series of professional development workshops, reunions with alumni, and by encouraging

them early on to apply to and participate in internships in both research and industry. From our MS program in Scientific Computing and Applied Mathematics, about 50% of graduates secure employment in the industry (private corporations), and the other 50% either go into a PhD program (at UCSC or elsewhere) or join a research position in a National Lab/Federal Agency (see alumni website). From our PhD program in Applied Mathematics, we similarly have about 50% of the graduates who secure employment in the industry, and 50% who take on academic positions or positions in federal laboratories (see alumni website).

While still very young and fairly small, our department is rapidly expanding. The recent launch of the MS program in Scientific Computing and Applied Mathematics, and the even more recent launch of the BS program in Applied Mathematics have been successful far beyond our expectations, and the rapid increase in the number of students attending these programs is expected to result in a continued increase in the number of faculty. The next future hire is planned in high-performance computing (finite elements) and further hires beyond that will solidify and complement existing research groups in data science/machine learning, fluids, control, mathematical biology, and stochastic modeling, with the goal of keeping the department at the cutting edge of applied mathematical research. Within the next 10 years we hope to establish ourselves as a strong, internationally-recognized Applied Mathematics department on a par with those in other public universities, such as CU Boulder, or the University of Washington, for instance.

### Facts, including ranking

1. How does this i**nstitution** rank nationally among its peers? Give two rankings from different sources, including dates and names of the sources. Please reference the National Research Council and *The Chronicle of Higher Education* and other specific rankings for this multidisciplinary program application. (Refer to Appendix for other ranking sources.)

The 2022-23 U.S. News and World Report ranked UCSC as follows:
- #7 for excellence in undergraduate teaching, among National Universities
- #18 for social mobility, among National Universities
- #35 in Top Public Schools, among National Universities
- #83 overall in National Universities

In 2021, U.S. News and World Report also ranked the Jack Baskin School of Engineering among the top 100 best graduate programs in engineering.

In 2022, Princeton Review named UC Santa Cruz the No. 2 public university in the nation for "making an impact", and No. 3 greenest college in the nation.

In 2019, the Association of American Universities elected UCSC into the association, an achievement that underscores the impact and quality of the campus's research and graduate and undergraduate education. The AAU, founded in 1900, has 65 members, including six other University of California campuses, flagship public universities such as The Ohio State University, land-grant universities like Purdue University, and private institutions such as Harvard. With the

distinction of being elected to the AAU, **UC Santa Cruz became one of only six universities that is both a Hispanic-Serving Institution and a member of the Association of American Universities**.

UCSC faculty include one [Nobel Laureate](#), 12 members of the National Academy of Sciences, 28 members of the American Academy of Arts and Sciences, and 40 members of the American Association for the Advancement of Science. Eight UC Santa Cruz alumni are winners of [ten Pulitzer Prizes](#) (two alumnae have won twice).

> 2.      How does this **department(s)/program(s)** rank nationally among its peers? Give two rankings from different sources, including dates and names of the sources. If the multidisciplinary program is not ranked, provide the rankings of the primary departments and any quantitative and qualitative comparative information for the program as a whole.

The Applied Mathematics department is very young (founded in 2018) and its graduate programs were split from the former "Statistics and Applied Mathematics" graduate program of the former joint department of Applied Mathematics and Statistics when the two departments separated. The Bachelor in Science program is younger still, and was launched in 2019.

Because of that, the UCSC Applied Mathematics programs are not listed in the US News of the World report (yet). The only official rankings we are aware of for UCSC Applied Mathematics are that of College Factual, who ranked the UCSC Applied Mathematics PhD program [#9 for Best Applied Mathematics doctoral programs](#), in the Far Western region of the United States (including California, Oregon, Washington). Our MS program in Scientific Computing and Applied Mathematics [is ranked #8 in California](#).

> 3.      How old is the **department/program or multidisciplinary program** and why was it established?

UCSC was founded in 1965 and the Applied Mathematics Department (and its graduate programs) was established on July 1, 2018, after being spun off from the Applied Mathematics & Statistics Department (which itself was established in 2007). This move was part of a general restructuring of the Baskin School of Engineering, which recognized the importance of Applied Mathematics as a standalone research area.

A unique feature of the Applied Mathematics Department at UC Santa Cruz is its strong focus on applications, which is reflected in both its research and teaching practices, and the fact that it is located within the School of Engineering. This is by contrast with many Applied Mathematics programs in the United States, a majority of which are part of larger Mathematics departments that also include Pure Mathematics. As a result, our faculty collaborate on a very regular basis with other faculty on the UCSC campus and beyond. Many of these collaborations include faculty in the School of Engineering (e.g. in Cyberphysical Systems, Control & Robotics, Bioinformatics & Genomics), and in the Physical and Biological Sciences division (e.g. in Astrophysics, Physics, Physical

Oceanography and Planetary Science). We regularly co-advise PhD students, giving the students a unique "dual" perspective into their research field, and much broader career prospects (i.e. in both applied mathematics and in their selected area of application).

**Degrees Granted**

    1.    Name the degrees awarded in the department/program or multidisciplinary program (e.g., PhD in Chemistry).

PhD in Applied Mathematics;
MS in Applied Mathematics;
MS in Scientific Computing and Applied Mathematics;
Designated Emphasis (i.e., graduate minor) in Scientific Computing
B.S. in Applied Mathematics;
Undergraduate minor in Applied Mathematics.

    2.    For which of the degrees named above are you seeking funding?

For the PhD in Applied Mathematics.

    3.    For each degree named in two, please indicate the number of degrees that are granted per year per faculty.

Between 2018 and 2022, the average number of PhD students per faculty was 2.8, and the average number of degrees granted per faculty is 0.28. This number is artificially skewed on the lower side because we have hired 3 faculty since Fall 2017, who have taken on a large number of PhD students, who have not yet graduated (since it takes on average 5.25 years to complete a PhD in Applied Mathematics, see below).

    4.    For each degree named in two, please indicate the non-completion rate.

Since Fall 2012, the program has trained 55 students who started in the PhD program. Of these 55, 24 have so far graduated with a PhD, 11 have graduated with an MS in Applied Mathematics (after deciding to leave the PhD program), 1 did not complete any degree, and 22 are still in the PhD program (these are students who started in Fall 2017 or later, who are expected to complete the PhD this coming quarter or later).

The student who did not complete any degree left the program after one quarter because of financial issues (cost of living in Santa Cruz / cost of attending the program).

    5.    For each degree named in two, what is the average length of time a student invests to receive a Doctoral degree in the department/program or multidisciplinary program being considered (using data from the past 10 years, if available)?

Since Fall 2012, the average length for completion of the PhD program has been 21 quarters (5 years and 1 quarter).

### Students

1. How many students are in the department/program or multidisciplinary program?

As of Summer 2022, there are 22 students in the PhD program (this number fluctuates from quarter to quarter owing to students graduating and/or joining the program). It is expected to grow substantially in the next couple of years with the expected faculty hires this year.

2. Explain the student mentoring effort and/or graduate support to enhance retention in the department/program or multidisciplinary program. Explain why if none is available.

The department of Applied Mathematics view mentoring holistically, covering several areas including:
- Research / academic progress
- Teaching (for students who are TAs)
- Professional development
- Student well-being

Each student is assigned an academic mentor upon joining the program, even if they have not yet selected a research advisor. The mentor ensures the student knows which classes to take, and meets with the student at least twice in the first year to discuss classroom progress, progress in identifying an advisor and the student's well-being. The meeting discussion is prompted by a set of questions provided to the student and advisor in advance of the meeting, to ensure that all points are addressed.

Once the student has selected a research advisor, the latter becomes their academic advisor as well. The two meet at least once a week to discuss research progress, and continue to meet twice a year to discuss classroom progress, overall progress in developing research skills, conferences to attend/professional milestones that need to be reached, and the student's well-being. After advancing to candidacy the student needs to identify a PhD committee, and meets on a regular basis with them as well. This ensures that the student has at least 2 or 3 additional senior scientists to discuss research, and overall professional development should they decide to pursue an academic career.

Given that a substantial number of our PhD students choose to join the private sector after graduating, we have also begun to offer in the past few years a series of professional development workshops, targeted to both MS and PhD students. These include for example an "How to find and

apply for jobs" workshop, "How to write a resume/CV" workshop, and an "Alumni panel" where program alumni discuss their current employment, how they got there, what they like about it, and many other topics.

Finally, students are provided several opportunities to improve their teaching skills, through teaching workshops offered by the Center for Innovation in Teaching and Learning at UCSC. These are particularly valuable for students wishing to pursue academic careers at all levels.

3.  On average, what financial assistance is available to each student? ARCS Scholar financial awards are unrestricted, and not to be included in the financial package award- ed by the institution.

Beginning in 2020, UC Santa Cruz offers new and continuing doctoral (PhD) and master's of fine arts (MFA) students support packages of 5 years for PhD or 2 years for MFA students, with a minimum level of support equivalent to a 50% teaching assistantship. All PhD and MFA students at UCSC can therefore expect financial support (stipend, fees, tuition, GSHIP, etc.) of approximately $43,000 annually.

In some departments, including Applied Mathematics, students paid through graduate student researcher (GSR) appointments are funded at a substantially higher rate. To provide equitable support to all students, the department of Applied Mathematics complements the teaching assistant (TA) stipends to match the GSR stipend for students who have already advanced to candidacy. This amounts to a yearly financial package of between $50,000 and $60,000 (depending on the student's seniority), not including summer salary. Summer salary is provided either through TA-ships (for those who are teaching during the summer) or through GSR-ships. In the latter case, the amount is at the discretion of the student's advisor.

**Faculty**

1.  What is the size of the faculty? How many faculty members are in the department(s) or program(s) or will be engaging with the scholar(s) in the multidisciplinary program?

As of Summer 2022, there are 9 full time ladder-rank faculty in the department of Applied Mathematics, with two planned hires for the 2022-2023 Academic Year (one authorized search, and one spousal hire). There are also 3 adjunct professors (from neighboring research institutions) who advise or co-advise graduate students (and provide funding for them), and finally several lecturers, who teach lower and sometimes upper division undergraduate classes. All full-time faculty and adjunct professors are engaged in mentoring PhD students. The program also has 1 emeritus faculty, Marc Mangel.

2.  What percentage of the faculty is full-time, part-time?

Prof. Marcella Gomez has recently been appointed Associate Dean for Diversity, Equity and Inclusion, which is a 50% administrative position, 50% academic position.

All other core program faculty (Brummell, Garaud, Gong, Halder, Jonsson, Lee, Venturi, Wang) are on full time academic positions.

Emeriti and adjunct faculty are formally 0% appointments.

3. <u>What is the faculty/student ratio for the department/program or multidisciplinary program?</u>

Between 2018 and 2022, the average number of PhD students per faculty was 2.8

4. <u>Cite national awards received by current faculty teaching in the department(s)/ program(s) or multidisciplinary programs in the past 5 years. (Additional rows should be added as needed.)</u>

| Faculty Name | Award |
|---|---|
| Vanessa Jonsson | NCI/NIH K12 Career Development Award |

5. <u>Cite national offices held by current faculty teaching in this department(s)/program(s) in the past five years. (Additional rows should be added as needed.)</u>

| Faculty Name | National Organization | Office Held |
|---|---|---|
| Pascale Garaud | Physical Review Fluids | Editorial Board (current) |
| Pascale Garaud | Geophysical & Astrophysical Fluid Dynamics | Associate Editor (current) |
| Pascale Garaud | Geophysical Fluid Dynamics Summer Program (WHOI) | Executive committee member (current) |

| | | |
|---|---|---|
| Qi Gong | AIAA Journal of Guidance, Control and Dynamics | Associate Editor (2019-2021) |
| Abhishek Halder | Systems and Control Letters | Associate Editor (current) |
| Abhishek Halder | IEEE Transactions on Aerospace and Electronic Systems | Associate Editor (01/19-12/20) |
| Abhishek Halder | IEEE Control Systems Society | Associate Editor (current) |
| Vanessa Jonsson | Immunoinformatics | Editorial Board (current) |
| Hongyun Wang | Open Physics | Associate Editor (current) |
| Hongyun Wang | Journal of Applied Mathematics and Bioinformatics | Editorial Board (current) |
| Hongyun Wang | Journal of Computational and Theoretical Nanoscience | Editorial Board (current) |

6.    How many and what percentage of current faculty in this department(s)/program(s) hold research grants from the National Institutes of Health (NIH), the National Science Foundation (NSF) and/or other nationally-recognized scientific bodies?

As of August 2022, **all of the 9 core faculty in the department hold at least 1 research grant** from nationally-recognized scientific bodies (many hold several). These come from NSF, NIH, NASA, DARPA, ARO, AFOSR, DOE and DOD and the 15 most significant ones are listed in Question 8.

Adjunct faculty have also raised significant extramural funding, and although that funding is not routed through UCSC, it is sometimes used to support PhD students (as well as MS students and postdoctoral researchers) in Applied Mathematics. For example, Steven Munch recently supported one of our PhD students, Bethany Johnson, on a GSR (after which she was awarded a competitive NOAA Sea Fellow Grant to complete her PhD). He also supported a postdoctoral researcher in Applied Mathematics, Dr. Cheng-han Tsai, for the past year (AY 2021-22).

7. How many current faculty have been elected to membership in the relevant organizations of: National Academy of Sciences; National Academy of Engineering; Institute of Medicine. (Additional rows should be added as needed.)

| Faculty Name | Organization |
|---|---|
| Pascale Garaud | Fellow of the American Physical Society 2019 |
| Marc Mangel (emeritus) | Fellow, American Association for the Advancement of Science, 2002 |
| Marc Mangel (emeritus) | Fellow, Society for Industrial and Applied Mathematics, 2013 |
| Marc Mangel (emeritus) | Fellow, Ecological Society of America, 2016 |
| Marc Mangel (emeritus) | Fellow, American Academy of Arts and Sciences, 2018 |

8. List the 15 most important current grants, including amounts, dates of funding, funding agency and role of faculty member (e.g., PI or Co-PI).

The following list are the top 15 grants currently held by our regular core faculty (the grants from adjunct faculty are not included here; also, grants for equipment are not included here).

- **Co-PI: Marcella Gomez** (Lead PI: Marco Rolandi, UCSC). "Bioelectronic Intelligent Control of Wound Regeneration (BETR).", DARPA, total amount: **$16.62M**. Dates: 01/20-12/23

- **Co-PI: Abhishek Halder** (Lead PI: Ricardo Sanfelice, UCSC). "CPS Frontier: Computation-Aware Algorithmic Design for Cyber-Physical Systems.", NSF, total amount $5.76M, UCSC portion: **$2.3M**. Dates: 07/22-06/27

- **Co-PI: Daniele Venturi** (Lead PI: Lise Getoor, UCSC) , "Institute for the foundations of data science'', NSF-TRIPODS, **$2.23M.** Dates: 09/20-08/25

- **Co-PI: Nic Brummell** (Lead PI: Todd Hoeksema, Stanford). "Consequences of Flows and fields in the Interior and Exterior of the Sun (COFFIES)", NASA, total amount: $15M; UCSC portion: **$1.5M.** Dates: 09/22-08/27

- **Lead PI: Pascale Garaud**. "Supporting and Mentoring the Next Generation of Scholars in Applied Mathematics", NSF S-STEM, total amount **$956,796**. Dates: 01/20-12/24

- **Co-PI: Daniele Venturi** (Lead PI: Ricardo SanFelice) "Verification and Validation of Autonomous Systems with Hybrid Dynamics Under Uncertainty'', AFOSR, total amount **$720,000.** Dates: 06/20-09/22

- **Lead PI: Abhishek Halder**. "Learning and Distributional Feedback Control for Fabrication of Advanced Materials", NSF, total amount **$650,461**. Dates: 08/21–07/24.

- **Lead PI: Dongwook Lee.** "Simulation of high-energy-density electron beams", DOE, total amount: $1.1M; UCSC portion **$555,000**. Dates: 09/22-08/25

- **Lead PI: Qi Gong**. "Collaborative Research: Algebraic Framework of Compositional Functions for New Structure, Training and Explainability of Deep Learning'', NSF, total amount: $1.18M; UCSC portion **$458,486**. Dates: 01/22-12/24

- **Lead PI: Daniele Venturi.** "Dynamically orthogonal tensor methods for high-dimensional time-dependent nonlinear partial differential equations", AFOSR, total amount: **$419,934.** Dates: 06/20-9/23

- **Lead PI**: **Daniele Venturi**. "Computational challenges in the numerical approximation of nonlinear functionals and functional differential equations'', ARO, total amount: **$404,187.** Dates: 06/18-05/23

- **Lead PI: Nic Brummell**. "The evolution of buoyant magnetic structures in the solar interior'', NSF AST, total amount: **$403,270.** Dates: 09/19-08/23

- **Lead PI**: **Hongyun Wang**. "Mathematical study of uncertainties in injury caused by non-lethal weapons", DOD, total amount: **$400,000**. Dates: 08/19-10/22

- **Lead PI: Qi Gong.** "Model-based Data-driven Learning Methods for Optimal Feedback Control", AFOSR, total amount: **$371,002.** Dates: 05/21-04/24

- **Lead PI: Pascale Garaud.** "Magnetized double-diffusive convection in stars", NSF AST, total amount: **$320,789.** Dates: 09/19-08/23

9.   State the number of published articles per faculty attributed to the department(s)/program(s) under consideration during the past two years (provide full citations for 10 examples, underlining and bolding faculty names) as well as the number of articles published by the department/program's faculty in the journals "Nature", "Science" and the journals that constitute the top three peer reviewed publications in your field/s during the past two years. Cite 10 examples.

Because it is sometimes difficult to establish the publication date of an article, we report here all articles with a publication **year** from 2020 to 2022.

The number of refereed papers published (or currently in press) by our faculty for the last few years are:
- 2022: 20 papers by 9 faculty
- 2021: 26 papers by 8 faculty
- 2020: 26 papers by 8 faculty

(note that these do not include conference proceedings). This represents an average of 2.9 refereed papers per faculty per year.

It is impossible to choose which are the "top 3" peer-reviewed journals in our fields (other than Nature, Science, and related products), because our department faculty span many distinct research disciplines, each of which has its own set of top journals. For this reason, we are selecting one "top" journal per research discipline according to the Google Scholar top publications list. In some cases where the top journal was in a discipline that none of our faculty work on, we discarded it as marked).

- Fluid dynamics: Journal of Fluid Mechanics (impact factor: 3.96)
- Astrophysics: The Astrophysical Journal (impact factor: 7.8)
- Control and Automation: IEEE Transactions on Automatic Control (impact factor: 6.12)
- Computational Mathematics (not mechanics and engineering): Journal of Computational Physics (impact factor: 4.59)
- Computational Biology (not bioinformatics): PLOS Computational Biology (impact factor: 4.78)

Based on this, our faculty have published a total of 25 papers in these top journals since 2020, as well as in Nature Communications, Nature Methods, and Nature Medicine.

Here are 10 salient examples spanning the various disciplines of our department. In many cases, the first author is a student advised by the faculty.

- Bucktrout S.L. et al. (including **Vanessa Jonsson**). "*A Roadmap for Immunotherapeutic Development by Single Cell Technologies*", Nature Medicine, To appear September 2022

- Carrión, Héctor, et al. (including **Marcella Gomez**), "*Automatic wound detection and size estimation using deep learning algorithms*", PLOS Computational Biology (2022), 18.3,

e1009852.

- Sanghi, A. Fraser, E. Tian and **Pascale Garaud**, "Magnetized oscillatory double-diffusive convection " (2022), The Astrophysical Journal, 935, id33

- Peng, K. et al. (including **Vanessa Jonsson**), "*Diversity in immunogenomics: the value and challenge*", Nature Methods (2021), 18(6), 588-591

- Y. Lee and **Dongwook Lee**, "*A single-step third-order temporal discretization with Jacobian-free and Hessian-free formulations for finite difference methods*," Journal of Computational Physics, (2021), 427, 11063

- B. Manek and **Nic Brummell**, ``On the Origin of Solar Hemispherical Helicity Rules: Simulations of the Rise of Magnetic Flux Concentrations in a Background Field'' (2021), The Astrophysical Journal, 909, 72

- Caluya, K. and **Abhishek Halder** "*Wasserstein proximal algorithm for the Schrodinger bridge problem: density control with nonlinear drift*", IEEE Transactions on Automatic Control, 67, pp. 1163-1178

- P. Lambrianides, **Daniele Venturi, and Qi Gong**, "*A new scalable algorithm for computational optimal control under uncertainty*" (2020), Journal of Computational Physics, Vol. 420, pp. 109710.

- Gupta, S., Ross, T. D., **Marcella Gomez**, Grant, J. L., Romero, P. A., and O. S. Venturelli, "*Investigating the dynamics of microbial consortia in spatially structured environments*." (2020), Nature communications, 11(1), 1-15.

- L. Cope, **Pascale Garaud** and C. P. Caulfield, "*The dynamics of stratified horizontal shear flows at low Peclet number*" (2020), Journal of Fluid Mechanics, 903, A1

Here are 10 more papers by our faculty published since 2020, which again showcases the diversity of topics addressed:

- Sargent, B., Jafari, M., Marquez, G., Mehta, A.S., Sun, Y.H., Yang, H.Y., Zhu, K., Isseroff, R.R., Zhao, M. and **Marcella Gomez**, "*A machine learning based model accurately predicts cellular response to electric fields in multiple cell types*" (2022). Scientific reports, 12(1), pp.1-13.

- **Hongyun Wang**, W. Burgei, S. Foley and H. Zhou "*Minimum energy requirement for inducing withdrawal reflex in millimeter wave exposures*" (2022) Journal of Applied Mathematics and Physics, 10, 2381-2406

- W. Kang and **Qi Gong**, "*Feedforward neural network and compositional functions*

*with applications to dynamical systems*" (2022), SIAM Journal on Control and Optimization, Vol 60, No. 2, pp. 786-813.

- Hughes, D. and **Nic Brummell**, ``*Double-diffusive magnetic layering*'' (2021), The Astrophysical Journal, 192, 195

- Dektor and **Daniele Venturi**, ``*Dynamic tensor approximation of high-dimensional nonlinear PDEs*'' (2021), Journal of Computational Physics, 437, p. 110295.

- **Pascale Garaud**, "*Journey to the center of stars: the realm of low Prandtl number fluid dynamics*" (2021) invited review, Physical Review Fluids, 6, 030501

- **Abhishek Halder**, "*Smallest ellipsoid containing p-sum of ellipsoids with applications to reachability analysis*" (2020), IEEE Transactions on Automatic Control, 66, pp. 2512-2525

- Stern, L, **Vanessa Jonsson,** Priceman, S., "*CAR T Cell Therapy Progress and Challenges for Solid Tumors*" (2020), Cancer Treatment and Research Communications, 180, pp. 297-326

- H. Ge, X. Zhang, C. Li, and **Dongwook Lee**, "*A Global Nonhydrostatic Atmospheric Model with a Mass and Energy Conserving Vertically Implicit-Correction (VIC) Scheme,*" (2020) The Astrophysical Journal, 898, 130

- **Hongyun Wang**, W. Burgei and H. Zhou "*Non-dimensional analysis of thermal effect on skin exposed to an electromagnetic beam*" (2020) American Journal of Operations Research, 10, 147-162.

### If this is a Multidisciplinary Program, please complete the following:

This is not a multidisciplinary program.

1. Provide a listing of multi-investigator grants and their size and source of funding relating to this department(s)/program(s).

2. What entity gives the degree? (What does the diploma say?)

3. Are there recruitment efforts in common between the multidisciplinary program and related departments/programs? If so, what are they?

4. If the Multidisciplinary Program involves more than one university or institute, please name all participating entities.

a. <u>Are all institutions participating approved by ARCS?</u>

b. <u>Please confirm that the degree-granting university is approved by ARCS.</u>

## SECTION II

Additional questions to be completed if the department(s)/program(s) or Institution housing it is/are **not** ranked within the top 50 in the nation. Many of these questions are answered in regard to the institution.

1. <u>Is the doctoral degree regularly awarded from this institution in the sciences, engineering, and/or medicine? Please state the number of degrees granted for each area, what degrees they are, and from what departments for the past 3 years.</u>

**School of Engineering Data (Cumulative over 3 years AY 2018-19, 2019-20, 2020-21)**

Applied Mathematics Dept:  6
Biomolecular Engineering Dept: 19
Computational Media Dept:  2
Computer Science and Engineering Dept:  29
Electrical and Computer Engineering Dept:  13
Statistics: 8

**Physical and Natural Sciences Division (Cumulative over 3 years AY 2018-19, 2019-20, 2020-21)**

Astronomy and Astrophysics Dept:  Astronomy and Astrophysics: 15
Chemistry and Biochemistry Dept:  40
Earth and Planetary Sciences Dept:  18
Ecology & Evolutionary Biology Dept:  35
Mathematics Dept:  17
Microbiology & Environmental Toxicology Dept:  5
Molecular, Cellular, & Developmental Biology Dept:  21
Ocean Sciences Dept: 15
Physics Dept:  Physics 31

**Social Science Division (Cumulative over 3 years AY 2018-19, 2019-20, 2020-21)**

Environmental Studies: 23

2. <u>What are the top three science, engineering and/or medical research departments at the institution?</u>

It is difficult to state which are the top departments without being given a metric along which to rank them.

**In terms of research expenditure, for AY 2020-21 (see below), the top three departments are:**

Molecular, Cellular, & Developmental Biology Dept:  $8,566,212
Ecology & Evolutionary Biology Dept:  $8,493,992
Chemistry and Biochemistry Dept:  $6,604,750

**In terms of cumulative number of PhD degrees awarded in the past 3 academic years:**

Chemistry and Biochemistry Dept:  40
Ecology and Evolutionary Biology: 35
Physics Dept: 31

**In terms of overall present doctoral degree enrollment:**

1. Chemistry and Biochemistry
2. Molecular Cell and Developmental Biology
3. Computer Science and Engineering & Ecology and Evolutionary Biology

However, these metrics are typically associated with the overall size of the department and (for research expenditure) costs associated with research (in particular, instrumentation costs).

**Research impact in 2021**

Given that UCSC is regularly recognized as one of the top universities in the nation in terms of research impact, another relevant metric can be created by looking at the most impactful faculty, and seeing which department they come from. [According to this website](#) the following UCSC faculty rank in the top 1% of most highly cited faculty in 2021, according to the Web of Science. These are (in no specific order):

- Galt  Barber, David Haussler, Hiram Clawson, Mark Diekhans, Maximilian Haeussler: **Biomolecular Engineering / UCSC Genomics Institute**

- Richard Bouwens, Jonathan Fortney, Garth Illingworth: **Astronomy and Astrophysics**

- Shaowei Chen: **Chemistry and Biochemistry**


3. Indicate the total expenditures at the institution for research activities in fields relevant to the department(s).

We provide the data for the last full academic year for which it is available on the institutional research, assessment and policy website (IRAPS), namely AY 2020-21. This data is publicly available on this site.

**Extramural Research Expenditures (direct costs, for AY 2020-21)**

Engineering
Applied Mathematics Dept:  $660,033
Biomolecular Engineering Dept:  $3,974,376
Computational Media Dept:  $923,367
Computer Science and Engineering Dept:  $3,720,855
Electrical and Computer Engineering $4,841,798
Statistics: $428,405

Physical and Natural Sciences Division
Astronomy and Astrophysics Dept:  $3,511,880
Chemistry and Biochemistry Dept:  $6,604,750
Earth and Planetary Sciences Dept:$3,240,995
Ecology & Evolutionary Biology Dept:  $8,493,992
Mathematics Dept: $92,328
Microbiology & Environmental Toxicology Dept: $2,463,799
Molecular, Cellular, & Developmental Biology Dept:  $8,566,212
Ocean Sciences Dept: $2,593,803
Physics Dept:  $743,434

Social Science Division
Environmental Studies: $1,598,716

4. Indicate the total expenditures in the department(s)/programs for research activities in the fields of science, engineering, and medicine.

The data provided below is the aggregated sum of individual department data provided above (direct costs only, for AY 2020-21), for each division.

- Extramural research expenditures for the School of Engineering:  $34,599,169
- Extramural research expenditures for Physical and Biological Sciences division: $49,765,512
- Extramural research expenditures for Social Sciences division (Environmental Studies Department only**)**: $1,598,716

Note that UCSC does not have a Medical School.

**Attachments**

Please list attachments

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**APPENDIX**

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**Ranking Sources**

The following is a suggested list of resources used to rank universities, colleges, and departments. This list is not all-inclusive; other ranking systems may better serve a particular academic discipline.

- **National Research Council** - http://sites.nationalacademies.org/PGA/Resdoc/

- **Chronicle of Higher Education -** https://chronicle.com/stats/productivity/page.php?year=2007&primary=5&secondary=117& bycat=Go

- **PhDs.org -** http://graduate-school.phds.org/

- **Center for College Affordability and Productivity -** This list includes only those institutions classified as research universities http://centerforcollegeaffordability.org/rankings/2013-rankings

- **QS Top Universities Ranking System -** Worldwide university rankings, guides and events http://www.topuniversities.com/

- **Center for Measuring University Performance Rankings of America's Top Research Universities, Public and Private Institutions, Ranked Separately** - http://mup.asu.edu/research.html

- **US News and World Report Graduate School Rankings** - http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools

**Hard and Soft Science Explanation**

**T**he Science Council gives this definition of science: "Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence." The council describes the scientific method as being comprised of the following components:

- Objective observation

- Evidence

- Experiment

- Induction

- Repetition

- Critical analysis

- Verification and testing

In general, those sciences that can easily make use of the scientific method as described above are termed "hard sciences," while those for which such observations are difficult are termed "soft sciences."

**The Hard Sciences**

Sciences that explore the workings of the natural world are usually called hard sciences, or natural sciences. They include:

- Physics
- Chemistry
- Biology
- Astronomy
- Geology
- Meteorology

Studies in these hard sciences involve experiments that are relatively easy to set up with controlled variables and in which it is easier to make objective measurements. Results of hard science experiments can be represented mathematically, and the same mathematical tools can be used consistently to measure and calculate outcomes.

**The Soft Sciences**

In general, the soft sciences deal with intangibles and relate to the study of human and animal behaviors, interactions, thoughts, and feelings. Soft sciences apply the scientific method to such intangibles, but be- cause of the nature of living beings, it is almost impossible to recreate a soft science experiment with exactitude. Some examples of the soft sciences, sometimes referred to as the social sciences, are:

- Psychology
- Sociology
- Anthropology
- Archaeology (some aspects)

Helmenstine, Anne Marie, PhD "What Is the Difference Between Hard and Soft Science?" ThoughtCo, Feb. 11, 2020, https://www.thoughtco.com/hard-vs-soft-science-3975989