

## **DEFINING THE FUTURE OF AERONAUTICS AT UCSC: A Proposal for A Computer Engineering Graduate Program in The Silicon Valley Focusing on Aeronautics Science and Engineering**

***Intellectual Rationale:*** The integration of Unmanned Aerial Systems (UAS) into the National Airspace provides engineering challenges that span across many fields, including robotics, autonomous systems, multi-agent systems, cyber-physical systems, modeling and optimization, systems analysis and integration, trajectory modeling and control, large-scale distributed simulation, cloud computing, network security, and big-data networking. The importance of UASs for both economic and defense-related purposes is unquestionable—and that importance is anticipated to grow dramatically in the future. Their economic roles include monitoring of land use, crop status, air quality, traffic and wildfires, as well as future applications in making deliveries and in law enforcement. Their anticipated importance moving forward represents the **most formidable** challenge for our Air Traffic Management (ATM) system in its history, which must evolve to be able to manage large numbers of UASs in the National Airspace. Designing modifications to our Air Traffic Management system alone represents a vibrant academic research area, with major groups at institutions such as UC Berkeley (UCB), MIT, Purdue, Stanford, and Maryland. From a complementary perspective, the technologies necessary to build, command and control UASs (including managing interactions between them—so-called “swarm” behavior) span the fields of Computer Engineering, Computer Science, Aeronautics, and Mechanical/Aerospace Engineering—and are an area that is undergoing rapid growth in engineering programs throughout the country (as one example, UCB, Georgia Tech, and Virginia Tech now have research centers or major facilities devoted to UAS research). The need for a smart national airspace system capable of monitoring, visualizing and simulating thousands of flights together with UAS activity at national scale poses research challenges in distributed visualization, simulation, cloud computing, and security for which answers are sorely needed.

Through its collaboration with NASA Ames, UCSC is poised to nucleate a state-of-the-art major research initiative and graduate program in aeronautics engineering, with a focus on ATM and Unmanned/Robotic Aerial Systems. Our plan focuses on the first faculty model stated in the call for proposals, i.e., building ladder-rank faculty in a specific area at the core of the future of computer engineering. We propose to do so by building on the campus expertise in information technology, computer engineering, and computer science, and the UARC staff expertise in ATM. We will start by offering our existing CE M.S. and Ph.D. programs in Silicon Valley (SV) with emphasis on aeronautics. Starting with six new faculty full-time equivalent (FTE) to be housed close by NASA Ames, and together with up to 25 UARC and Ames-affiliated adjunct faculty, we will expand the vibrant research enterprise on robotics, cyber-physical systems, data science, storage, networking, and visualization at the UCSC campus. We will work on the creation of a Ph.D. program on aeronautics within the first three years of the program, followed by the possible creation of a new department of aeronautics engineering in SV. We will determine whether the creation of a new department in SV is feasible once the graduate aeronautics program reaches maturity within five years from its inception. The proposed program and possible future aeronautics engineering department will train students to be entrepreneurs and be employed by SV industries, NASA, Caltrans, Department of Transportation, airport authorities, the Federal Aviation Administration, consulting companies, and academia.

***Involvement of Existing Faculty, Adjuncts, and UARC Staff:*** A large number of UCSC SOE faculty (including adjuncts) are engaged with aeronautics related-research, and key research areas related to ATM and UAS research. The ladder-rank faculty and research interests in CE include: W. Dunbar (complex systems), G. Elkaim (UASs), J.J. Garcia-Luna-Aceves (networking, cyber-physical networks, cloud computing), D. Milutinovic (ATM), K. Obraczka (mobile networks), R. Sanfelice (hybrid control); and the following adjuncts: R. Curry (UASs), B. Sawhill (ATM) and M. Teodorescu (UASs). Within CS, adjunct faculty C. Maltzahn and ladder-rank faculty A. Pang each have strong interests in this domain; and within AMS, the following ladder-rank faculty: Q. Gong (satellite

control), H. Lee (optimization), and A. Rodriguez (reliability) have aeronautics-oriented interests, as does J. Kubby (MEMS) in EE. Among the various UCSC departments with interest in aeronautics, CE is the natural choice to lead this initiative, because it has the strongest presence in this vibrant area involving robotics and computer networks, as well as the most robust curricular base that can be augmented to produce a suite of graduate-student study plans focusing on aeronautics engineering. CE faculty members have ongoing projects with NASA Ames researchers in a number of areas of interest to the proposed program. However, the existing collaborations are not part of a campus-wide effort.

This proposal takes advantage of the extensive but not fully explored institutional engagement in this arena: currently, UCSC employs ~65 full-time employees associated with the Aeronautics Directorate at NASA Ames. NASA aeronautics-related work that runs through UCSC's University Affiliated Research Center is typically ~\$15 million/year. It is the pre-eminent ATM research group in the federal government, serving FAA as their major customer, but also airports, airlines, and equipment manufacturers. While many of the faculty members we have listed have collaborated with investigators at Ames, the academic engagement between UCSC faculty and NASA in aeronautics is not large when compared to the current scale of business engagement (primarily because of our small faculty cadre). Our plan is to utilize existing aeronautics infrastructure at Ames, our proposed six UCSC SV faculty infusion, and the large-scale funding opportunities in the aeronautics domain at NASA to *leverage the creation of a premier academic enterprise in Aeronautics Science and Engineering, with a large and vibrant graduate program*. To this end, we are in the process of appointing through CE five new adjunct faculty members from our UARC staff (Musaffar, Chatterji, Malik, Lee, and Drew). All of them are distinguished aeronautical engineers and are committed to mentor graduate students and teach graduate courses. They have teaching experience at institutions such as Georgia Tech, Texas A&M, and Santa Clara University. We view these new recruits as a first installment of 20-25 appointments of UARC and Ames-affiliated adjunct faculty in association with this program.

***Enrollment Goals and Connection to Campus Research:*** Given the large size of the aeronautics enterprise at Ames (our UARC aeronautics work and employees are only one component of the aeronautics enterprise at Ames), their unprecedented workforce replacement issues (Ames has the highest average age of civil servants of any government lab), and our existing staffing base, we believe that a target goal of 40 graduate students is achievable in the near term (2-5 years), with expansion to 50-70 possible at program maturity. These enrollment goals are feasible because of the large role that Ames researchers will play in the program as adjunct faculty teaching courses and co-advising graduate students. These students would likely be approximately evenly divided between M.S. and Ph.D. students, and will particularly have tremendous opportunities to work at NASA Ames during their graduate program (e.g., via the current NASA Education Associates Program – <http://eap.usra.edu>, or the new One Stop Shopping Initiative (OSSI) program – <http://intern.nasa.gov>) and post-graduation.

The connections to campus research will involve extensive interactions with our existing faculty: indeed, we anticipate that the closer ties with the aeronautics enterprise of Ames and the UARC (or its successor) will enable a class of UAS and ATM research that we have not conducted on the campus to date (as examples, NASA has the ability, through its FAA Certificate of Authorization, to fly much larger UASs, at higher altitudes than the line-of-sight required locally; and it has state-of-the-art, full-scale air-traffic management system simulation capabilities). The CE program will benefit greatly from the Aero/Mechanical capabilities brought to bear by this program: for example, those who work on control systems will have immediate access to investigators who build the mechanical systems on which their control systems are deployed. In a very real sense, this program could fill the research gap within SOE associated with our campus' lack of Aero/Mechanical Engineering.

***Target Market and Evidence of Demand:*** Our target market is two-fold. Our immediate market consists of talented engineers who already work in SV and who are interested in Air Traffic

Management or the rapidly expanding world of Unmanned/Robotics Aerial Systems. We are also targeting undergraduate students graduating from universities in SV or near SV who are attracted by the possibility of collaborative research with NASA in the context of graduate studies, and the job opportunities offered by the expanding field of aeronautics.

However, the future of aeronautics in the U.S. is posed to revolutionize computer engineering as we know it by transforming embedded systems, mobile computing, internetworking of things, and robotics into cyber-physical networks operating in the ambient environment. Furthermore, NASA will have high-impact research with national and international notoriety in this area. Hence, our long-term market is in fact the computer-engineering graduate student of the future. UCSC can become a magnet for the best graduate students in many areas of engineering.

The demand can be illustrated in different ways: the present forecast for procurement and R&D associated with UAS is projected to rise from \$5.2 billion to \$11.6 billion over the next decade.<sup>1</sup> Similar efforts by the Air Force Office of Scientific Research,<sup>2</sup> and the Army Research Office<sup>3</sup> also forecast a dramatic growth in the demand for experts in aeronautics and aerospace robotics. If current forecasts of extensive utilization of UASs by Amazon, Google and others occur, these estimates may prove to be markedly conservative. Within the governmental domain, hundreds of positions come open each year from attrition at NASA and the FAA: even without expansion of these areas in the government sector in response to the technical challenges that are emerging within the next decade, workforce replacement alone will produce a vibrant job market for graduates (and, conducting graduate work at a NASA lab often leads to civil servant jobs).

**Outline of Resource Needs:** UCSC has the unique opportunity to become *the* leading UC campus in aeronautics engineering in a very short period of time, and at a time when the field of aeronautics is about to explode with innovation and new jobs. However, our campus needs to take decisive steps shaping the leadership of this program in Silicon Valley. For this program, we propose to follow a funding model based on ladder-rank faculty that takes full advantage of dozens of adjunct faculty obtained from NASA, as well as SV companies in the future. We propose to hire one senior FTE focused on UAS; one senior FTE focused on ATM; and one senior FTE recruited in the broader field of Aeronautical Engineering in Years 1 and 2, and 2-3 junior FTE in a similar distribution of fields and other fields we identify in this domain in years 2-4. One of these first three senior positions will be recruited and appointed as the leader of the UCSC Silicon Valley Aeronautics group, with the remaining two providing key intellectual leadership in other areas that are vital to the scope of the program. The initial start-up expenses (beyond space acquisition and renovations, the expenses for which are difficult to assess) should be start-up packages for engineering faculty that are competitive with those on the main campus, or ca. 600-1000 K per faculty. The rationale here is that, while impressive infrastructure is available through collaborations with NASA, recruiting superlative faculty will require a fiscal commitment for laboratories and infrastructure that allows them to construct/equip laboratories to conduct their own research. This, however, constitutes a modest investment, given that the outstanding faculty we will recruit will be extremely successful at leveraging the NASA-facing aspects of the program, in addition to providing outstanding student mentorship. In terms of space, a commitment of Silicon Valley classroom space will be required, and it is likely that SV office space and dry lab/computer lab/benchtop space will be required for each new faculty FTE hired (probably at the level of ~1500-2000 sq. ft./hire, given that UAS-centric labs can be quite space intensive). Graduate student office space will also be necessary, with a likely commitment of ca. 5000 sq. ft. (including common space that is critical for the generation of a cohesive program/graduate student cadre). Finally, miscellaneous administrative support space of ~750 square feet will also likely be required.

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<sup>1</sup>[https://www.faa.gov/about/office\\_org/headquarters\\_offices/apl/aviation\\_forecasts/aerospace\\_forecasts/2014-2034/media/Unmanned\\_Aircraft\\_Systems.pdf](https://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2014-2034/media/Unmanned_Aircraft_Systems.pdf)

<sup>2</sup>[http://www.au.af.mil/au/awc/awcgate/af/af\\_roadmap\\_2006-25.pdf](http://www.au.af.mil/au/awc/awcgate/af/af_roadmap_2006-25.pdf)

<sup>3</sup><http://www-rucker.army.mil/usaace/uas/US%20Army%20UAS%20RoadMap%202010%202035.pdf>