ASTROBIOLOGY PROGRAM

University of Washington

Self-study Document

February 2011

Prepared for

the Graduate School's 5-year Review of the Astrobiology Certificate

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Section I. Overview of Organization [http://depts.washington.edu/astrobio]

I.1 Mission & Organizational Structure

The mission of the UW Astrobiology Program is to provide world-class graduate training in the interdisciplinary field of Astrobiology. To do this, we currently offer a graduate Certificate Program, which is attained in parallel with the student's graduate degree in their home department. Our mission and graduate Certificate program is described in Sec. I.1.2 below. Statistics for our enrollment and graduates are given in Sec. I.1.3.

Our management structure consists of a Steering Group that coordinates all Astrobiology (AB) matters. Sullivan is current Chair (appointed by the College of Arts & Sciences Divisional Dean of Sciences) and other current members are Deming, Ward, Catling, and Meadows, as well as Rika Anderson (Oceanography) as graduate student representative. The Steering Group has operated now for over a decade in an enjoyable, collegial manner. It manages and coordinates recruitment, program evaluation, faculty and staff issues, coordination of research programs, teaching of graduate and undergraduate courses and seminars, other AB events, tracking of AB student progress, public outreach, and fund-raising.

I.1.1 What is astrobiology?

Astrobiology deals with life in a cosmic context, and is only fifteen years old as a field of study. Its birth was catalyzed by the discovery of planets circling other stars, microbial life here on Earth living in extremes of temperature, pressure and chemistry, evidence for liquid water elsewhere in the solar system, and studies of the earliest history of life on Earth. Our central research theme is to understand (a) the origin, evolution, distribution and future of life on Earth, and (b) the conditions

on other potentially habitable planets, so as to inform where and how we should search for fossil or extant life on other worlds. Life exists on Earth under an amazingly wide range of conditions that may well exist on other planetary bodies, e.g., Mars or Jupiter's moon Europa or extrasolar planets. But whether or not any extraterrestrial life is ever found, astrobiology topics are of fundamental scientific value. The field continues to excite scientists and the public alike with, for example, recent discoveries of (a) geysers of water spurting through cracks in the surface ice of Saturn's moon Enceladus, (b) five candidate planets of Earth-like mass orbiting in the habitable zones of their stars, and (c) microbes living in high arsenic levels that may have lead to incorporation of this normally toxic element into the microbes' DNA.

I.1.2 Graduate program

We are a graduate-only program with core courses, seminars, field workshops, and research rotations required for our Certificate in Astrobiology, which accompanies a student's PhD. We produce top-quality students – for example, our students have placed in the top 4 posters (out of typically ~ 50) at *each* of the six NASA Astrobiology conferences over 2000-10; many other students have been invited to give oral presentations. Our graduates are now holding postdoctoral and junior faculty positions in many prestigious locations (Sec. II.1.2).

Astrobiologists must be thoroughly conversant with many disciplines, and expert in one or more. They must be able to do complex, multi-faceted science, and then explain it to audiences (both scientific and lay) who are unfamiliar with most of the underlying details. Producing such scientists under today's typically restrictive, department-dominated academic structure is difficult, but we have striven to breach the walls separating disciplines.

Our AB Program has evolved from an academic experiment into the international educational leader of an emerging scientific discipline. Staley (2003), which describes our program and its philosophy, is attached as Appendix K. We have developed and implemented an interdisciplinary curriculum with unique features that bond together students and faculty from disparate departments. Each AB student has deep expertise in one field, plus sufficient knowledge in other areas to foster interdisciplinary research, especially between biological and physical sciences. Our students are imbued with an interdisciplinarity that is highly unusual and sorely needed in today's scientific community and in society at large.

A standard claim of ours (and others acknowledge it, too) is that the UW AB Program has by far the most *coherence* of existing AB efforts at major universities. The AB Program *as a Program* has breadth and consistency: (a) there exists a genuine interdisciplinary "AB philosophy" in how we train our students, (b) the

program spans almost the full disciplinary range of astrobiology, and (c) the students and faculty know each other and work together well.

So that our students not become "academic orphans," we have *not* created a new PhD (although we discuss our current effort to change to a dual-title degree in Sec. IV and App. G). Each student is firmly rooted in a home department — and gets the PhD there — but also spends considerable time becoming familiar with the broad range of science needed in AB. Our students' unique AB credentials are serving them well as researchers in universities and government labs; as educators in academia (research universities and liberal arts colleges); as savvy administrators of increasingly interdisciplinary programs; and as science writers or journalists (see App. H for the current positions of our graduates).

Our Program requires highly motivated students: they expend ~15-20% more total effort than their non-AB peers. Our courses and seminars differ from the usual because of the diversity of student backgrounds and range of topics. They are not "dumbed down" versions of "proper" graduate-level courses, but rather new constructs — intense, high-level, and very challenging for both students and faculty. Instructors maintain a fast pace and introduce only essential background and terminology, without sacrificing understanding of core principles and concepts.

The specific requirements for the AB Certificate are summarized in Sec. II.1.1, with further details in the Program's Student Guide given in Appendix F.

I.1.3 Our History

In 1998, thirteen UW faculty (from nine departments) received a 5-year $2.2M NSF IGERT (Interdisciplinary Graduate Education and Research Training) grant for AB (PI: Prof. James Staley of Microbiology). This allowed us to establish our AB graduate program and Certificate, the first formal AB program in the world. Our first cohort of graduate students entered in 1999 and our first Certificate was earned in 2003.

In 2000 we received an internal UW grant (a University Initiatives Fund (UIF) sponsored by the College of Arts & Sciences; PI: Prof. Woodruff Sullivan of Astronomy) to set up the Center for Astrobiology and Early Evolution, which is an "on-paper" center under whose rubric UW astrobiology activities are coordinated. In 2001 we used those funds to hire two new faculty specifically for the AB Program: Prof. Roger Buick of Earth & Space Sciences (ESS), who studies micro-paleontology and geochemical biomarkers in the oldest geological formations, and Prof. David Catling, then of Atmospheric Sciences, who models the history of planetary atmospheres, in particular Earth and Mars. Catling left the UW for 2005-09, but we were delighted to lure him back in 2009, now as part of ESS. Our third core AB faculty, Prof. Vikki Meadows (Astronomy), was hired in 2007 and leads an interdisciplinary team developing models of extrasolar planetary environments and

spectra, with the goal of assessing the detectability of planetwide habitability and life via telescopic observations. UW departments have also made several other supportive faculty hires, e.g., in Astronomy (Prof. Tom Quinn) and Microbiology/Civil and Environmental Engineering (Prof. David Stahl).

Renewal of IGERT grants is even more competitive than the initial grants; we were not successful in our first renewal attempt in 2003, but nevertheless carried on through prudent spending and no-cost extensions until our successful $3.2M renewal that began in 2005 and ends 30 June 2011 (PI: Sullivan).

In 2001 we received a 5-yr, $5.0M NASA grant (PI: Prof. Peter Ward of Biology) for AB research on "Habitable Planets and Evolution of Biological Complexity." This research funding was a vital complement to the IGERT grant. The NASA funding, for example, allowed us to support talented foreign students (not allowed by NSF's regulations) and postdocs. It permitted a vigorous research effort to accompany our graduate education program, and made us a member of NASA's Astrobiology Institute (NAI). Our current NAI membership is through the Virtual Planetary Laboratory Team (PI: Meadows, 2007-12). This grant was originally awarded to Caltech, but was brought to UW with Meadows when she was hired. It now provides similar complementary benefits for research and graduate student and postdoc support, although over a narrower swath of AB research.

Today the AB Program has 22 participating faculty, listed in Appendix C. These faculty hail from 8 departments (Aeronautics & Astronautics, Astronomy, Atmospheric Sciences, Biology, Earth and Space Sciences, History [of Science], Microbiology, and Oceanography) and 4 Colleges or Schools (Arts & Sciences, Environment, Medicine, and Engineering). The 5 key departments in terms of active faculty and student participation are Astronomy, Biology, Earth and Space Sciences, Microbiology, and Oceanography (which still involves us with 4 Deans!); see Table 1. Table 1 is organized by departments and belies the tremendous amount of cross-mentoring that takes place in terms of faculty and students interacting with each other through doctoral committees, research rotations, workshops, and courses (see Sec. II.1.1). As with any organization, our strength lies in the quality of our people; the CV's of our faculty (links in Appendix C) attest to their excellence, including two members of the National Academy of Sciences (Brownlee and Deming).

We have 24 regular AB graduate students (in 5 departments) and 7 associated post-docs. To date we have awarded 19 AB Certificates and are now averaging about 3 per year.

It should be emphasized that although we have many faculty and students on our rolls, they are all parttime to varying degrees. We are basically a small program compared to even small academic departments. Although we have one major research grant from NASA and have had a major educational grant from NSF, much of what gets done by faculty with respect to the AB Program is voluntary. We have

a staff of only 1.0 FTE (0.5 of which is via UW matching funds) and rely heavily on our constituent departments for recruiting and advising of graduate students.

Table 1. Statistics for Astrobiology Program members (Winter 2011)

31 total faculty on our roster, of which:

1 is in Europe (Thomsen)
2 are emeritus
6 are Affiliate

Of the remaining 22 (listed below), 17 are subjectively judged as "active" in the Program (in 6 depts.) and 7 as carrying ~75% of the load for the Program (in 4 depts.)

	Faculty				Total
Dept.	full	ret/affil.	Students	Advisors	Certificates Awarded
Astronomy	5	0	5	3	4
ESS	10	1	12	7	6
Microbiology	1	3	1	1	3
Oceanography	3	3	4	2	6
Biology	1	0	2	1	
Aero/Astronautics	1	0			
Atm. Sciences	1	0			
Genome Sciences	0	1			
History (of Science)	(1)	0			
Totals	**22**	**8**	**24**	**14**	**19**

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I.2 Budget & Resources

The UW Astrobiology Program has had these primary sources of support:

- IGERT program (NSF) (1998 start; ends 30 June 2011)
- NASA Astrobiology Institute (2001-05; 2007-2012)
- Arts & Sciences budget (2000-)
- UW matching funds for NSF and NASA grants

- Private donations

The annual **IGERT Program** funding is $650K ($610K after 8% indirect costs), of which 70% is spent on NSF fellowships for our students, on average 9 students at any one time. Each student annually receives a $30K stipend, benefits, tuition support, and a $2K research kitty. Our policy has been to support each AB Certificate student for 2.0 years; the rest of their graduate study is covered by other faculty RA funds and UW TA's (typically for 0.3 to 1.0 year, depending on department). The remainder of the IGERT funds, which NSF severely restricts in their flexibility (e.g., foreign students are excluded), go primarily for salaries (50% of our Coordinator and 8% of the PI), assessment, student travel for research and conferences and rotation projects, undergrad research jobs, annual workshop expenses, office expenses, seminar speakers, and short-term visitors.

NASA Astrobiology Institute funding is for the Virtual Planetary Lab (PI: Meadows) and, although largely allocated to collaborators at other universities, has still provided an average of $330K/yr spent at UW since 2008. These funds benefit a subset of AB faculty and graduate students for research expenses that include graduate student support, summer salary, publication expenses, travel, workshop support, supercomputing equipment and support, supplies, and Education/Public Outreach.

The only state funds supporting the Program are via the **College of Arts & Sciences** (growing out of the UIF Award in 2000). These amount to $22K/yr, which goes for graduate student and faculty travel to astrobiology conferences, small research needs, public lectures, office expenses, partial summer salary for the Steering Group Chair, and general needs for the program (e.g., Web and publication expenses).

UW matching funds to the NSF and NASA grants have been critical in our success, both in their quantity and greater flexibility. For example, we had 3 RA-ships/yr tied to our first NASA grant; these were used almost exclusively for the foreign students, among the best in the Program, but who cannot receive NSF (IGERT) monies. The NASA grant also received, for example, matching equipment funds from the UW (e.g., for a mass spectrometer).

For our second IGERT grant, we received significant matching funds from various UW units, primarily participating departments and colleges. This support was a measure of the confidence that the various units had in our program after its first five years. The main items included: (1) 50% of the Program Coordinator salary (Vice Provost for Research); (2) space for the Coordinator and an RA slot each year for assessment (Sec. II.2.1) (Graduate School); (3) support for the AB Extremophile Lab ($15K/yr: College of Ocean and Fisheries Sciences); and (4) an additional $52K/year in cash from participating colleges and departments for research and travel expenses for grad students (especially the foreign students excluded from

IGERT funds), teaching supplies, support of visitors (mostly seminar speakers), undergrad research jobs, computer and Web support, and other program needs. A portion of these funds not yet spent will be available after June 2011 and help our transition off the IGERT grant by paying, for example, for a workshop or two, seminar speakers, some student travel and research expenses, and administrative costs.

Other federal research grants to individual AB faculty members, primarily from NSF and NASA, are of course also critical to our success and in fact support any given student for in most cases the majority of his/her career; here we discuss only the major grants specifically for AB.

Private donations have also been helpful over the years, amounting to a total of ~$40K. Our plans to increase philanthropic income are in Sec. IV.

Section II. Teaching & Learning

II.1 Student Learning Goals and Outcomes

II.1.1 Requirements for the Graduate Certificate in Astrobiology

The AB curriculum includes graduate-level core courses and seminars, field workshops, and a research rotation, all required *in addition to* each student's departmental requirements.

Core courses. ASTBIO 501: Astrobiology Disciplines. This provides an introduction and concise background to core concepts and essential terminology of the relevant disciplines contributing to AB. Each week a faculty expert in one area is teamed with an incoming student also knowledgeable in that area. If a week's lecture topic is, for example, paleontology, a faculty paleontologist works closely with a graduate student (who has studied some paleontology) to prepare two lectures, one by the faculty member, the other by the student. The pair also lead a lab exercise or a discussion of a recent paper. This format has worked very well, greatly enhancing faculty-student interactions.

ASTBIO 502: Astrobiology Topics. This consists of one or more parts, coordinated by an AB faculty member and each led by an AB faculty expert. One part often ties in with the Annual Workshop topic. Examples have included "Life on Mars?" and "Extrasolar planets and habitability."

Also required is a third interdisciplinary cognate course, chosen from a list of existing courses, as well as suitable special topics courses (see App. F for examples).

The AB Seminar series. During fall and spring we invite outside speakers who give jargon-free introductions to their topic for part of their lectures, to enable

those in other fields to understand the research results that follow. These seminars, over a broad range of topics, have been well attended and are webcast to all NAI groups around the country (with an archive available online). During winter quarter we hold an "in-house" seminar series (three are required for the Certificate) that pairs faculty and students across disciplines to give presentations on a particular AB topic. For example, during the topic of "Planetary Atmospheres" a biology student lectured on the Martian atmosphere, after working closely with an atmospheric scientist. This winter series fosters close student interaction with faculty from other fields and provides a valuable learning and teaching experience. Topics have included "the origin of life," "biosignatures" (this current quarter), "extremophiles," and "ethics in AB" (offered every three years and required).

Field workshops. The annual 2-5-day workshop has become an excellent opportunity for informal off-campus interaction and instruction of both students and faculty. Workshops have been for example at the UW's Friday Harbor Marine Biology Lab (paleontology of the late Cretaceous, plus examination of invertebrates gathered off the ocean floor to learn about the Cambrian Explosion), Eastern Washington (evidence for catastrophic floods that produced the Washington "Channeled Scabland" terrain, similar to some ancient landscapes on Mars), Kitt Peak National Observatory (hosted by the University of Arizona NAI team), Yellowstone Park, and in 2010 in the Mojave Desert (geology and microbiology, including Chris McKay of NASA Ames as one of our faculty).

Research rotation. Every AB student must spend at least one quarter working in a lab outside his/her area of expertise (usually on campus with an AB faculty member, but some are off campus); upon completion, an oral presentation is also given. Examples: (1) a geology student studying desert "rock varnish" rotated through a microbiology lab, leading to a paper on microbes associated with varnish formation; (2) a biology student participated in the engineering development of a new spacecraft sterilization technique at Kennedy Space Center; (3) a microbiology student analyzed the statistics of exoplanet orbits in order to assess their long-term stability; and (4) a biological oceanographer studied analogies between changes in science two centuries ago (when today's disciplines became defined) and today's emergence of astrobiology (leading to a paper in the *Intl. Journal of Astrobiology*, 2009).

Thesis. Each student's PhD thesis committee must include one or two AB faculty members from outside the home department, and at least one chapter in the thesis must be relevant to astrobiology.

II.1.2 The Graduate Students

Our efforts have led students to innovative interdisciplinary work and thinking. They are excited by their exposure to such a variety of disciplines, and to

the fundamental nature of the questions raised by astrobiology, many of which form at the interface between disciplines and would not otherwise arise. Several students have commented that, in comparison to their peers as observed at (for instance) the annual AB Graduate Conference, their background has far more coherence and richness: as one AB student put it: "At UW the AB Program offers *an interdisciplinary culture*, not just interdisciplinary research." Another AB/Astronomy student related that the program had not just taught him some new things, but had fundamentally changed how he thought about his core Astronomy courses— he is now constantly looking for the nexus between the cosmos and the phenomenon of life. Finally, students have realized how their different "AB way" of learning has already profoundly affected their own teaching as TAs.

Several of our AB grad students were coauthors of chapters in a graduate textbook for AB (see below); in addition, one chapter was written solely by AB graduate students (Wells, Armstrong and Huber 2007) on the topic of the nature of Astrobiology, as well as its future. A sample:

> In the end, astrobiology may bring us back to the integrative style of someone like Johannes Kepler four hundred years ago. He was not content merely to bequeath the world a detailed quantitative theory of orbital motion, but instead wrote a great synthesis of the Universe. He understood it as a musical masterpiece, an orchestra of resonating orbits and celestial movements. Why are we scientists? - why are we teachers? - why are we curious? - if not to ask the grand questions that we cannot answer. Astrobiology is an opportunity for science to reincorporate some of the intemperance and ambition of earlier, more comprehensive approaches. No guarantee exists that these types of approaches will necessarily lead to fundamental insights, but if the equivalent of Kepler's famous Laws should emerge from the next great synthesis, this grand new enterprise of astrobiology would have proved its worth.

To date we have awarded 19 AB Certificates (the first in 2003) and these alumni are very successful; see Appendix H for a complete list. As staff scientists at national labs we have Julie Huber (Oceanography) at MBL (Woods Hole) and Steve Vance (ESS) at JPL. As faculty members we have John Armstrong (Astronomy) (Weber St., Utah and a VPL member) and Matt Schrenk (Oceanography) (East Carolina U. and a member of the Carnegie NAI team). Postdocs include alumni at NASA/Ames, Lunar & Planetary Lab of U. of Arizona, Wisconsin, Princeton, Northwestern, and Queens (Canada).

Other indications suggest that a not insignificant portion of our graduates will be attracted to non-standard endeavors, either as important components of

traditional careers, or as careers in science writing and speaking to the public, teaching at all levels (from high school to graduate school), museum work, studying the relationships of science with history, philosophy, and technology, and science administration with a uniquely comprehensive scientific background. This variety we regard very positively: society needs PhD students who intimately understand science and aspire to other than the academic scene. An outstanding example is Llyd Wells (Oceanography), now on the faculty of famed St. John's College, widely known for its rigorous "Great Books" curriculum.

II.1.3 Undergraduate Courses

We teach once or twice per year the very successful ASTBIO 115 (also cross-listed as Biology 114, Oceanography 115, Astronomy 115, and ESS 115!), a 5-credit introduction to astrobiology for nonscience majors. This course is extremely popular with undergraduates and also provides an excellent opportunity for some of our grad students to have a TA experience. We have been limited by available UW funds as to how many sections we can offer (usually only 1 TA covering 50 students in two sections, but a few times we have been able to get funded for two TA's and 100 students). Our AB students have also produced a lab activities manual for this course. Over the years several AB faculty have also taught 300 or 400-level special topics courses on Astrobiology for science majors, but we have not yet instituted, say, ASTBIO 350 designed for science majors; this we plan to do (Sec. IV). We do *not* feel it appropriate to fashion an undergraduate major in Astrobiology, as it would be a mistake for an undergrad science student to become too spread out in their knowledge; an undergraduate needs to become thoroughly grounded in one of the traditional sciences and study astrobiology only for further enrichment. We have considered the possibility of an undergraduate *minor*, but simply do not have the resources to run such a program.

II.2 Instructional Effectiveness & Assessment

II.2.1 Formal Assessment

With our IGERT funds we were able to afford formal assessment by the UW's Center for Innovation and Research in Graduate Education (CIRGE). Each year CIRGE conducted written and/or oral interviews with a portion of the various stakeholders such as students, faculty, department chairs and deans, and alumni. These studies led to seven formal reports issued over 2006-10, included as Appendix L (see separate pdf file). Here we give an executive summary.

Over the years the consensus of the polled and interviewed students was overwhelmingly positive towards the AB Program. The aspects that they felt needed

some improvement were the manner in which Rotation projects are advertised and administered; more interaction among the AB *faculty* (ideally as much as among the students!); and a desire to move from an AB Certificate to a dual-title PhD program (see Sec. IV.3).

Department chairs and deans were also consistently positive towards the AB Program and felt that it had significantly contributed to the intellectual life of their departments and of the University as a whole; their main concern was whether or not the AB Program would be able to maintain its vibrancy and health once IGERT funding ceased.

The survey of (9) AB alumni in Spring 2010 (all in academia or government labs) also revealed very positive attitudes towards the Program in terms of how it had positioned them in their careers and prepared them for interdisciplinary work.

II.2.2 Diversity in the AB Community

Our record for successfully recruiting and graduating under-represented minorities and women is similar to that of our constituent departments. We made several major efforts with IGERT funds such as (1) establishing an alliance with historically black universities (led by Tennessee St. U.) where we had faculty contacts, (2) contributing 20% of the salary of a UW staff member hired specifically for increasing the number of under-represented minorities in the sciences and engineering, and (3) putting on an "AB Institute" (June 2007), an intensive week of lab, classroom and field experiences aimed at under-represented minorities and women undergraduates from around the country. Unfortunately, (1) and (2) in the end frankly did not work despite a lot of effort; for (3), several of the students did go into the sciences and to graduate school, but not into astrobiology.

In 2005 minorities were 9% and women were 27% among our graduate students; currently the figures are 8% (two African-American women) and 54%. Our AB faculty include no minorities, and women are also under-represented (14%), although one of our three AB-hired faculty is a woman. We will continue to work with our constituent departments and campus organizations such as GO-MAP to enhance the diversity in our program.

We pride ourselves in the international scope of our students and faculty (all three of our AB-hired faculty are foreign-born), and have encouraged our students to do their Rotation projects and attend conferences and develop collaborations overseas. We have had AB students from India, Botswana, Germany, Colombia, Canada, and Switzerland. Rotations have been executed in Germany, France, England, Denmark and Australia.

II.3 Teaching & Mentoring Outside the Classroom

The AB Program works with its constituent departments in the recruitment, retention, and general advising of its graduate students. Departments have very different cultures in this regard – here we describe only what our Program specifically does. First, with regard to recruitment we have our own AB Admissions Committee that vets applications for admission to the AB Program each winter quarter. These applications are mostly from graduating seniors, but we also admit first-year UW grad students. In each department "local" AB faculty members work closely with their departmental admissions committee, for in effect each department has veto power over any decisions that we might want to make. We also peruse incoming applications of those students who look ideal for us and yet have *not* applied to AB, usually because they did not know about the Program. Many of them can be persuaded to apply once they learn what we have to offer.

The AB Steering Group annually reviews the status and progress of each AB student. This review is preceded by an advisor-student meeting where progress towards the Certificate is documented and other issues are discussed. The advisor then reports to the Steering Group, which after discussion decides on what message to pass on to the student regarding adequate progress, etc. Appendix F (the AB Student Guide) gives more details.

A major issue for each student is the choice of a Rotation project (Sec. II.1.1), which must be planned in detail by the end of the student's second year and ideally finished by the end of the third year. Prof. David Catling is our current "rotation czar" who solicits faculty for suitable projects, approves student plans as submitted, and in the end certifies that the project was adequately completed.

The annual 2-5-day AB Workshop (Sec. II.1.1) provides an ideal field experience for AB faculty to interact with and mentor students, as both faculty and students focus on the subject matter at hand, but approaching it from varied disciplinary angles. Community coherence is also enhanced by our annual AB hike, September AB Orientation and salmon barbecue, AB "socials" once a quarter on a Friday afternoon, and the AB students' own get-togethers. A special experience has been an informal Friday-afternoon seminar on Origin of Life led by Prof. John Baross and attended by many students for multiple years; the group is now finalizing a publication to be submitted to the journal *Astrobiology*.

Section III. Scholarly Impact

III.1 Highlights of Research Accomplishments

Our faculty are so productive and diverse that it would be impossible in a few pages to summarize their research over the past five years. Rather, here we give a sampling of highlights, emphasizing major results produced by our AB students, who of course were being mentored by and collaborating with AB faculty. Our students' awards at conferences have been discussed in Sec. II.1.2.

AB/Oceanography student William Brazelton (advisor: Baross) made important discoveries at the Lost City hydrothermal vent field in the mid-Atlantic, and published these in *Proc. NAS* (2010). Fluids venting at Lost City are generally at 90° C or less, highly alkaline, and enriched in methane and hydrogen – important energy sources for the microorganisms living in the vents that range in age from those newly formed to others tens of thousands of years old microbes. Analyses by Brazelton and colleagues revealed that DNA sequences that were rare in younger vents were abundant in older ones, indicating that microorganisms can remain rare for a long time before completely turning the tables to become dominant when ecosystems change. Because it is likely that the older Lost City chimneys released higher-temperature, higher-pH fluids when they were younger, as the ecosystem changed, the rare microorganisms came to the fore.

AB/Astronomy student Nate Kaib (advisor: Quinn) used computer simulations to show that the inner Oort Cloud (in the far outer part of the solar system) is a significant and perhaps the dominant source of long-period comets, contrary to previous understanding. He used this result to place the first observationally motivated upper limit on the population of bodies orbiting in this region of the solar system. Because this reservoir supplies the Earth-orbit-crossing comets produced during comet showers triggered by close stellar passages, he showed that these events have most likely not caused any major extinction events in the Earth's fossil record (*Science*, 4 September 2009).

To understand how a habitable planet is formed and evolves, we must understand the nature and history of planets orbiting other stars, of which over 500 are now known. AB/Astronomy student Nick Cowan (advisor: Agol) followed up his study of data from NASA's Spitzer Infrared Space Observatory that showed that a planet orbiting another star has a "hotspot" at a certain location on its surface. His new analysis, published in the *Astrophysical Journal* (2009), indicates that the general technique should be applicable to many more planets, and allows unprecedented inferences about planetary winds, temperatures, and pressures. Cowan then used these techniques on NASA's EPOXI mission observations of the unresolved Earth (advisors: Agol and Meadows) to show that his technique could be used to map the positions of different surface types, such as continents and oceans,

on a “pale blue dot.” The resulting paper (Cowan et al. 2009, *Astrophysical Journal*) was entitled “Alien maps of an ocean-bearing world.”

AB/ESS student Sanjoy Som (advisor: Montgomery) made a study of the geology of the Valles Marineris canyon region of Mars, characterized by extensive layering similar to what one sees in the Grand Canyon. The layering is not uniform, but deformed, as often seen on Earth. On Earth this so-called "cross-bedding" can be due to wind processes (forming sand dunes, which then get compressed into rock), or to the action of liquid water causing ripples, as on the bottom of a stream. Because liquid water is essential for life as we know it, astrobiologists are very interested in establishing whether and for how long liquid water existed on the surface of Mars in the past. In the case of Valles Marineris, Som and collaborators concluded that earlier results claiming that the strata were definitely formed by water were incorrect, and that a wind-driven process is also possible. Studies such as this are vital in helping NASA choose the best landing sites on Mars for seeking fossil evidence of life.

In the near future, space-based telescopes will record spectral features of Earth-like extrasolar planets that will be perhaps indicate that the planet can or does support life. In order to better design such a telescope, AB/Astronomy student Ty Robinson (advisor: Meadows) developed a 3-D spectrally and spatially-resolved model of the Earth, which includes reflection from the Earth’s oceans and scattering from realistic clouds, and rigorously validated it against observations of the distant Earth taken by the EPOXI interplanetary spacecraft. The resultant model has many applications for understanding the detectability of signs of habitability and life, and has been used, for example, to quantify the detectability of glint from an alien ocean, especially in the presence of clouds. Robinson showed how the effects of ocean and clouds could be disentangled by future extrasolar planet observations from space (Robinson et al. 2010, *Astrophysical Journal*).

AB/ESS student Jessica Garvin (advisor: Buick) was lead author on an article in *Science* (15 Jan. 2009). Her research involved measuring the isotopic ratios of nitrogen in 2.5-billion-year-old rocks from Australia in order to constrain how nitrogen was processed at that time between the Earth's rocks, atmosphere, and microbial life (the nitrogen cycle). Garvin and colleagues concluded that microbes at that time were actively processing nitrogen (as they do today), despite the fact that much less oxygen was in the atmosphere than now. This is the earliest evidence that we have for nitrifying and denitrifying microbes.

III.2 Influence within and outside UW

We have helped build mechanisms and the climate for successfully instituting innovation in interdisciplinary graduate education. Six other IGERT awards to UW

have since followed ours; a recent example of a *non*-IGERT program that sought our advice as it began is the interdisciplinary UW Program on Climate Change.

Beyond UW, dissemination of our program's practices informally and through talks at meetings has definitely influenced several other universities (Penn State, Arizona State, U. Arizona, Stockholm U., etc.) as well as the NASA Astrobiology Institute. We have also influenced AB pedagogy through the first graduate-level AB textbook, *Planets and Life: The Emerging Field of Astrobiology* (eds.: astronomer Sullivan and microbiologist Baross: Cambridge U. Press, 2007). The chapter authors, 40% from the UW, are drawn mainly from the invited speakers at a very successful conference on AB hosted by us. All 27 chapters, covering the gamut of AB, are designed to be understandable to any science graduate student who wants to learn the basics, no matter what her background. Our AB pedagogical philosophy suffuses this book – its publication has disseminated our conviction that graduate training *is* possible and needed across traditional disciplines. Appendix J, the prologue to *Planets and Life*, expresses our philosophy on the emerging field of astrobiology and how to train students in this field.

In addition to popular articles and books, many of us frequently appear on radio shows, in newspaper articles, and in video (PBS Nova, Discovery Channel). Locally, the AB Program sponsors two public lectures annually on AB topics – these typically draw crowds of 200-400; this year the lectures are by William Martin (origin of life) and Ralph Lorenz (Saturn's moon Titan). In the autumn of 2009 the AB Program sponsored a major series ("Life in the Universe") of six public lectures (including our own Profs. Jody Deming and Peter Ward) on many aspects of Astrobiology, on the occasion of the 400th anniversary of Galileo's telescope and the 150th anniversary of Darwin's publication of *On the Origin of Species*. These were widely advertised on and off campus and very well received – each drew an audience of 250-400. As an intended by-product, we now also have a database of over 500 email addresses for future publicity and for fundraising purposes. We also produce two AB Newsletters per year with short articles on current research and other activities of the Program, distributed to a mailing list of ~400 and an email-list of ~600; two recent examples are included in Appendix E.

In January 2010 Ward was honored as the recipient of the 34th Annual UW Faculty Lecture, for which he gave a talk to 700 persons on "Who's afraid of the big bad climate? What is the worst that global warming could do?" Ward's talk emphasized his work in the AB Program.

Our faculty are also recognized internationally as leaders in astrobiology education. In the summer of 2005 Baross and Sullivan were part of the faculty at a four-week Summer School on Astrobiology (for seniors and beginning grad students from around the world) sponsored by the Vatican (Jesuit) Observatory in Italy. Twenty-five excellent students from around the world were exposed to a wide variety of astrobiology topics, and one of them (a woman from Colombia) is now an

Oceanography/AB student. In 2009, Baross was invited as one of the faculty at the NAI/Centro de Astrobiologia one-week Summer School in Astrobiology on "Earth's Extremophiles and Extraterrestrial Habitability," held in Santander, Spain; and in 2010 Meadows was one of the faculty for the same summer school with the topic "Extrasolar Planets and Habitability." In April 2011 Baross will be one of three faculty for a Saas-Fee (Switzerland) school entitled "From Planets to Life."

With support from NSF IGERT and NASA, a group of our AB students organized and hosted the annual Astrobiology Graduate Student Conference (ABGradCon) on the UW campus in the summer of 2009. The organization involved weekly meetings over the course of six months to plan out logistics and publicity, as well as the scientific contents of the conference. These meetings and the conference itself immensely enhanced interaction between students of different disciplines in the UW AB Program and beyond. A particularly noteworthy experience was the introduction of "Second Life" as a virtual online platform to facilitate long-distance participation. Two of our AB students also participated in the organization of the 2010 ABGradCon, which was held in Sweden. One of them is also leading the development of an international Charter document for the ABGradCon conferences.

IV. Future Directions

The 2005 review panel described the Astrobiology Program at the University of Washington as "the leading program in this discipline both nationally and internationally. It provides the broadest educational training, has the largest student enrollment and has faculty participation from the widest variety of departments and colleges compared to programs at any other institution worldwide….the UW Astrobiology Program is currently at the very top of its field, and is a recognized leader in astrobiology graduate education and astrobiology research at the national and international levels."

Our goal is to maintain this level of excellence and pre-eminence for the UW Astrobiology Program, while we broaden its disciplinary range, improve its educational attainment, and strengthen its financial basis.

The Astrobiology Program at the University of Washington is now, in many respects, a mature and established entity, having been in existence for over a decade. However, the unit needs to maintain its interdisciplinary breadth, especially in those areas that have suffered from retirement of contributing faculty. Recent retirements include those in the areas of microbiology (Prof. Jim Staley) and chemical oceanography (Prof. Richard Gammon); others are imminent. Further, the Program needs to deepen its educational offerings beyond the current graduate-level courses (and the single 100-level offering for non-science majors) in order to consolidate its

position in the pedagogical repertory of the university. It also needs to strengthen its financial footing so that it relies less on temporary grants to fund the majority of its operations.

If these issues can be successfully addressed (and, as will be discussed below, plans have been made to do so), the Astrobiology Program will be headed towards our goal of sustainable and enhanced excellence at national and international levels. We believe that this can be achieved over the next few years, particularly if stable funding can be assured.

IV.1 Opportunities

The Astrobiology Program intends to pursue several opportunities to consolidate its position in the next few years in the areas of research, education, and funding sustainability.

The interdisciplinary breadth of our faculty and their research projects is sufficiently large that it would be difficult to find an all-encompassing funding source, especially in the post-IGERT era. Consequently, we plan a multi-pronged approach to financial stability that includes:

1. Maintaining our current affiliation with the NASA Astrobiology Institute (NAI) through the "Virtual Planetary Laboratory" (VPL) Team.
2. Applying for an NSF Science and Technology Center grant to study interactions between biological and atmospheric processes.
3. Coordinating efforts to address other NASA and NSF funding sources for complementary projects that support additional AB faculty and their students, such as the Deep Carbon Observatory and the NASA Exobiology Program.
4. Working with UW Development to strengthen and broaden the base of private donors for our "Friends of Astrobiology" fund for graduate student support.

In addition to these efforts to fund faculty and graduate student research and educational activities, we will seek to replace retiring faculty and maintain the strong interdisciplinary breadth of the program by:

1. Actively recruiting new Astrobiology faculty from existing faculty in relevant departments
2. Encouraging departments to make new hires that have astrobiology-relevant expertise and interest.
3. Asking for a junior AB faculty hire in the field of biochemistry and the origin of life.

Furthermore, the AB faculty make-up has lately shifted towards the physical sciences, so the Program would especially benefit from additions in AB-relevant biosciences.

In the area of astrobiology education, we wish to maintain the excellent quality of our graduate student population by increasing the pool of applicants via:

1. Offering a dual-title PhD in a student's home department discipline and Astrobiology
2. Active promotion of the program within the UW and to the external community.

Additionally, we wish to augment our existing undergraduate courses with:

1. A cross-listed ASTBIO 350 course for junior and senior science majors.

IV.2 The Program's Benefit and Impact

As noted above, the previous review panel assessed the Astrobiology Program at the University of Washington as "the leading program in this discipline both nationally and internationally." If anything, the program is now stronger than when that previous assessment was made, as it now has a third dedicated faculty member (Prof. Vikki Meadows), it has graduated an additional 15 students, most of whom found astrobiological employment in academic or government positions (App. H), and it has published many more high-impact research findings. In only one area, that of funding sustainability, is the program now in a weaker position than previously.

In terms of regional and statewide impact, the program brings to Washington's leading research university a cohort of superior interdisciplinary graduate students that enrich the intellectual environments of their departments (students that otherwise may have not chosen to attend this university), a considerable amount of research and educational grant money, and much positive publicity. Additionally the program sponsors public lectures and seminars that are very well attended, performs educational outreach at local schools, and (with NAI-VPL) is developing a prototype high-school astrobiology course for eventual use statewide. Having the top program nationally in astrobiology at the University of Washington brings prestige to the University and enriches our regional profile in aeronautical/astronautical engineering research.

If financial sustainability can be achieved and the program enhanced in the ways outlined in this section, we envisage that the high national and international reputation of the program will be maintained. Thus the benefits and impacts currently accruing from the program to the region, state, nation and world will be

sustained into the future. Moreover, by broadening its scientific range and its educational offerings, the AB Program's interdisciplinary intellectual influence will reach a wider group of undergraduate and graduate students.

IV.3 Implementation Plan

The initiatives described above will be implemented as follows:

Funding and Research

We will propose to renew our current NAI grant. At present, the NAI VPL grant headed by Prof. Vikki Meadows resides within the AB Program. The management of VPL moved to UW when she was hired in 2007, but as it is currently structured its research funding flows to a fairly small number of faculty, postdocs and graduate students, principally in the Department of Astronomy. In the renewal proposal (expected in late 2011), this base will be broadened to include more personnel in other AB-affiliated departments working in the areas of early Earth evolution and planetary science. Moreover, a greater proportion of the requested funding will support UW AB graduate students, which will partially compensate for the impending cessation of NSF IGERT student support in June 2011. Though renewal will be a difficult and highly competitive process, we feel confident that there is a good chance for success because of the previous scientific achievements of the VPL team, its innovative structure as a "virtual" node, and the high regard for the UW Astrobiology Program as a whole within NAI.

We are also considering applying for an NSF Science and Technology Center grant to cover some of the research areas not already supported by the NAI VPL grant, specifically the interactions between biological and atmospheric processes and how they evolve through time. We have been exploring this funding possibility, which if successful would bring in roughly equivalent funding to that from NAI and could support a wider range of faculty and student research. Depending on how the proposal is structured and who chooses to participate, it has the potential to cover many of the gaps in the AB scientific spectrum that will be left with no student support from the IGERT grant.

In addition to these larger proposals, some stability for the program could be obtained through coordinated proposal efforts from a number of faculty to a variety of smaller programs that offer funding for astrobiology relevant research, such as the NASA Exobiology and Planetary Atmospheres programs. Funding obtained in this way could be used to support a cohort of several graduate students.

However, even with the renewal of the NAI VPL grant and/or success with an NSF Center grant, there would still be unfunded areas of astrobiology activity once the IGERT grant expires. This is because research funding typically cannot be used

for anything other than research activities. In particular, salary for a program administrator, funding for seminar speakers, money for field workshops, and support for student research rotations and other minor research expenses will still need to be found elsewhere. We propose to do this in several ways:
i) to seek UW internal funding for the 0.5 FTE administrative position
ii) to seek grants from the NAI Director's Discretionary Fund (DDF) (if we remain part of NAI), as well as student scholarship support for field trips and workshops
iii) to encourage private donors to contribute to the "Friends of Astrobiology" fund.

We have had considerable success in DDF and conference support from the NAI, including awards in 2008-9 (PIs: Peter Ward, Mark Claire, Sanjoy Som-AbGradCon), 2009-2010 (Eva Stueeken-AbGradCon), and 2010-11 (Mark Claire, Jody Deming). To increase private donations, we have organized public lectures to attract potential donors, and developed a list of attendees and other interested individuals. This effort continues and is being coordinated with development specialists at the college level. Our solicitations are always for support of the graduate students. To date we have raised a total of ~$40K in donations over the past decade, but we are fostering long-term relationships and have the ambitious goal (but not impossible in Seattle) of eventually securing a $3-5M endowment that would fund an annual suite of graduate fellowships.

Faculty Recruitment for Scientific Diversity

Though the Astrobiology Program now has a stable core of dedicated faculty appointments (Profs. Buick, Catling and Meadows), many of the other affiliated core faculty have recently reached or are nearing retirement age. In order to maintain the scientific diversity of the program, we will encourage departments to make new hiring decisions bearing astrobiology in mind so as to replace astrobiology-active faculty on retirement. Moreover, we will attempt to broaden the academic range of the program by encouraging participation from existing faculty in under-represented areas such as biochemistry/origin of life and engineering. Though we have attempted this in the past, specifically by designing a new course on Life-detection Engineering Design, the effort foundered because the additional work-load was too great for the faculty concerned, who had their own departmental teaching obligations. With this in mind, future efforts will be directed to modules in the existing course ASTBIO 502 "Astrobiology Topics" or to components of the in-house Winter Seminar. We will also continue to attempt to find an interested UW chemist or biochemist to join the Program to fill the weakness in our current scientific profile in the area of prebiotic/origin of life chemistry, but a more likely solution would be a new junior hire by the Program in this field (see below).

The Dual-Title PhD in Astrobiology

We have initiated the process of switching from offering successful graduate students a Graduate Certificate in Astrobiology on top of a departmental PhD, to rewarding them with a dual-title "PhD in (Department) and Astrobiology." Appendix G contains our pending application to the Graduate School. This change has been motivated by student demand and by the example of the astrobiology program at Pennsylvania State University, perhaps our principal national competitor for students. The change will require minimal alteration to our current course offerings and little extra work from students, but is perceived by students to markedly enhance their status as astrobiologists and to confer considerable benefits for post-graduate employment. We also expect it to be a useful tool for student recruitment.

It is too early in the development of the field to offer a PhD purely in Astrobiology (nor do we seek a Department of Astrobiology), even though the field is strong and well funded and an increasing number of ads for postdoc and junior faculty positions seek astrobiology skills. The dual-title PhD is an excellent compromise that maximizes job prospects for our graduates by ensuring that our students have the full education expected from a PhD in their home department, but with added training as interdisciplinary scientists in the field of astrobiology.

We are planning a 2-3-day workshop on "Advanced AB Education" to be held here at the UW next winter. Invited will be academics involved in AB education, who an learn from each other, but also NASA (including NAI) officials whom we want to persuade to set up a scheme of federal AB traineeships.

Undergraduate Coursework

To consolidate the range of AB courses offered, we will develop a cross-listed ASTBIO 350 course for junior and senior science majors to complement our ASTBIO 115 course for non-science majors. Though we have considered doing this in the past, there has not until now been sufficient faculty resources available to realize this goal. The ten-week syllabus will necessarily vary depending on the instructor, but we will insist that in no case does it devolve to only the astrobiological aspects of the instructor's own home discipline. In many cases it would best be team-taught, but this always raises difficulties with assigning appropriate teaching "credit" to the faculty members involved.

IV.4 Resources from the UW

We have outlined above our plans to continue the AB Program's success, as well as to improve it in several ways. As our 2005 review panel stated, "the

challenge for the UW is to maintain and promote the excellence that has been achieved." Over the past six years the UW and the AB Program together have met this challenge well. In order to further the stated missions of the UW with regard to teaching, research, and public service, as well as to act in accord with the UW President's and Provost's strong past support of interdisciplinarity, we submit that the UW could do no better than invest further in the Astrobiology Program, even in these difficult fiscal days. Here we present a list of the resources, in approximate order of priority, that we request to maintain our leadership in the field and to go from strength to strength.

1. **Funding for 0.5 FTE Program Administrator** (~$30K/yr) – a Program as large as ours and with as many activities simply cannot survive without a post such as this. (To date, our IGERT grant has paid for 0.5 FTE and the Office of Research 0.5 FTE; starting in July 2011 we will tighten our belt and reduce the position to 0.5 FTE.)

2. **A new junior faculty hire in Astrobiology within the next 2-3 years**, ideally in the area of prebiotic chemistry and origin of life. As with our previous successful searches, we envision an interdisciplinary search committee that seeks the right person for the Program in terms of (a) firstly, her/his interdisciplinary astrobiological teaching and research abilities, and (b) secondly, the specific home department and chief research area. This position could be split between departments or Colleges (such as between Environment and Arts & Sciences).

3. **One TA-quarter per year for our 5-credit introductory course ASTBIO 115**. Presently, we have to ask each time in an *ad hoc* fashion and are not able to plan ahead in assigning instructors and TA's.

We are grateful for past support and for consideration of these requests to invest further in the Astrobiology Program.

PART B. Unit-defined Questions

The way we have organized Part A of this Self-Study has in fact already addressed almost all of the "unit-defined questions" that were submitted six months ago. Three questions (#1 and 2 and 8) dealt with how to survive in the post-IGERT regime and that has been covered in Sec. IV and earlier. Two others (#6 and 7) dealt with whether or not to keep the same requirements for the Certificate and/or offer a new dual-title PhD. We have forged ahead with applying for the latter (Sec. IV), although we we still offer the Certificate for those students who satisfy all

requirements except that their thesis does not have sufficient AB content. As discussed in Sec. IV, we feel that our greatest teaching and research weakness is in prebiotic chemistry and origin of life research (#4), but we ask the Committee's advice on this issue. We do not feel that our present administrative structure needs to be changed (#5), although the Committee's advice here too will be valuable. In particular, sometime in the next year or two Prof. Woody Sullivan would like to turn over the AB reins so that someone else can reign in Seattle's rain.

The question (#3) as to how to foster and accredit teaching duties for cross-departmental courses has been a vexing one from the start of AB 12 years ago. The 2005 Review Committee discussed this and stated that the upper echelons of UW administration needed to promulgate policies that would help innovative interdisciplinary Programs such as ours. Six years later things remain unchanged, with substantial inequities amongst departments when AB faculty wish to teach AB courses: do they get "credit" for it, or can they only do it as a voluntary overload?

Another question that we would like the Committee to investigate is whether our Program could be feasibly supported in part by receiving a portion of AB faculty members' RCR that would normally go to Colleges or Departments. Our faculty members favor this idea, but can Deans and Department Chairs support such a concept?

At the Charge meeting in November, the Committee set forth three further questions for us to consider. The first dealt with the effect on AB of the creation of the new College of the Environment, which includes one of our key departments (ESS). To date we have seen no particular effect, but we are just starting an effort to discuss AB's future with Dean Graumlich. We will inform the Committee of developments before their visit in April.

The second question raised the issue of the UW's new "Activity Based Budgeting." We are informed by A&S Divisional Dean Werner Stuetzle that the College of A&S will *not* be using ABB in its decisions for how to divvy up funds *within* the College. At least for the present, it thus appears that the small State-funded line that AB has ($22K/yr) will not be affected by ABB-think.

The Committee's third request was to supply information on our plans for the dual-title PhD in "X and Astrobiology." Our plans, largely modelled after the successful nanotechnology dual-title PhD, are discussed in Sec. IV.3 and given in detail in App. G.

ASTROBIOLOGY PROGRAM

Self-study Document – February 2011

APPENDIX A: Organizational Chart

	Phone (206)	Email.washington.edu	Box 35+	Department/Office
STAFF				
Quense, Nancy	616-4929	nquense@u	7242	Grad School, Loew
FACULTY				
Agol, Eric	543-7106	agol@astro	1580	Astronomy/Physics, PAB B370
Bandfield, Josh	685-1910	joshband@u	1310	ESS, JHN 347
Baross,John	543-0833	jbaross@u	7940	Oceanography, MSB 260
Brown, Mike	616-6058	brown@ess	1310	ESS, ATG 220
Brownlee, Don	543-8575	brownlee@astro	1580	Astronomy, PAB C331
Bruckner, Adam	543-6143	bruckner@aa	2400	Aero/Astronautics, Gugg 211E
Buick, Roger (lv Ja10-De10)	543-1913	buick@ess	1310	ESS/AB, JHN 335
Catling, David	543-8653	dcatling@u	1310	ESS/AB, JHN
Delaney, John (a)	543-4830	jdelaney@u	7940	Oceanography, MSB 274
Deming, Jody	543-0845	jdeming@u	7940	Oceanography, MSB 370
Felsenstein, Joe	543-0150	joe@gs	5065	Genome Sci/Biol, Foege S420B
Gammon, Richard	221-6744	gammon@u	5351	Ocean/Chemistry, OSB 409
Gillespie, Alan	685-8265	alan@ess	1310	ESS, JHN 343
Harnett, Erika (a)	543-0212	eharnett@ess	1310	ESS, JHN 267
Kelley, Debbie	543-9279, 685-9556	kelley@ocean	7940	Oceanography, MSB 264
Leigh, John	685-1390	leighj@u	7242	Microbiology, HSS E311
Meadows, Vikki	543-0206	vsm@astro	1580	Astronomy/AB, PAB B374
Montgomery, David	685-2560	dave@ess	1310	ESS, JHN 341
Murray, Jim (a)	543-4730	jmurray@u	5351	Oceanography, OSB 413
Nelson, Bruce	543-4434	bnelson@u	1310	ESS, JHN 433
Nerad, Maresi (IGERT)	221-3429	mnerad@u	3600	College of Ed, Miller M204
Quinn, Tom	685-9009	trq@astro	1580	Astronomy, PAB B380
Samudrala, Ram	732-6122	ram@compbio	7242	Microbiology
Stahl, David	685-3464, -8502	dastahl@u	2700	Civil/Env. Engin, MOR 302
Staley, Jim	543-0461	jtstaley@u	7242	Microbiology, HSS F329
Sullivan, Woody	543-7773	woody@astro	1580	Astronomy/Hist, PAB C318
Thomsen, Laurenz (a)		l.thomsen@iu-bremen.de		Jacobs Intl. Univ., Bremen, Germany
Ward, Peter	543-2962	argo@u	1800	Biology, KIN 162
Warren, Steve	543-7230	sgw@atmos	1640	Atmos Sci/ESS, ATG 524
Winebrenner, Dale	543-1393	dpw@apl	5640	ESS/APL, APL
Winglee, Robert	685-8160	winglee@ess	1310	ESS, JHN 070J
Wood, Steve (a)	543-0090	sewood@ess	1310	ESS, JHN 247
POST-DOCS				
Barnes, Rory	616-5001	rory@astro	1580	AB/Astronomy, PAB B376
Claire, Mark	616-4549	mclaire@astro	1580	Astronomy, PAB B351
Cowan, Nick	616-2788	cowan@astro	1580	Astronomy, PAB B356F
Dobbs-Dixon, Ian	685-2150	ianmdd@gmail.com	1580	Astronomy, PAB C304
Domagal-Goldman, Shawn	616-5001	sgoldman@astro	1580	AB/ESS/Astronomy, PAB B376
Matrajt, Graciela	685-0542	matrajt@astro	1580	Astronomy, PAB B327
GRAD STUDENTS				
Anderson, Rika	543-0546	rikander@u	7940	Oceanography, MSB 254
Ballanti, Loren	214-5396	oceanic@u	1800	Biology, KIN 162
Bowman, Jeff	425-753-3735	bowmanjs@u	7940	Oceanography, MSB 362
Brazelton, Billy	221-5755	braz@u	7940	Oceanography, MSB 214
Carns, Regina	562-505-0912	rcarns@u	1310	ESS
Cash, Michele	543-0208	mcash@u	1310	ESS, JHN 239
Colangelo-Lillis, Jesse	235-5174	jessecolangelolillis@gmail.cor	7940	Oceanography, starting W09
Costa, Kyle	702-429-3344	kccosta@u	7242	Microbiology
Ewert, Marcela	543-0147	mewerts@u	7940	Oceanography, MSB 364
Ewing, Samantha		ewings2@u	1310	ESS
Fuchsman, Clara	547-1321	cfuchsm1@u	7940	Oceanography, OSB
Garvin, Jessica (on leave)		garv@u	1310	ESS
Goldman, Aaron	650-906-8944	adg1000@u	7242	Microbiology, HSB
Harnmeijer, Jelte	543-9419	jelte@u	1310	ESS, JHN 323
Hillbun, Kelly	650-274-9832	khillbun@u	1310	ESS
Igbinosun, Osa (a)	585-732-1640	osaig@u	1310	ESS, JHN 262
Kaib, Nathan	616-4549	kaib@astro	1580	Astronomy, PAB B351
Kirkpatrick, John	543-1355	kirkpatr@u	7940	Oceanography, OSB 412
Kundurthy, Praveen	543-9095	pkundurthy@astro	1580	Astronomy, PAB B339
Lim, Sujung (a)	605-7858	amarth@u	7242	Microbiology
Misra, Amit (a)	440-554-6514	amit0@astro	1580	Astronomy, PAB B351
Opatkiewicz, Andrew	616-9041	opatka@u	7940	Oceanography, MSB 366
Robinson, Tyler	543-6276	robinson@astro	1580	Astronomy, PAB B333
Sauter, Linda	523-4046	lmsauter@u	7242	Microbiology, Ben Hall IRB
Shields, Aomawa	543-6554	aomawa@astro	1580	Astronomy, PAB B323
Smith, David	609-610-2166	djsone@u	1800	Biology, Kincaid
Snowden, Darci	930-4850	dsnowden@u	1310	ESS, JHN 262
Som, Sanjoy	685-1707	sanjoy@u	1310	ESS, ATG 211
Stueeken, Eva		evast@u	1310	ESS, JHN 336
Tobin, Tom	813-545-1912	ttobin@u	1310	ESS, JHN 423

ASTROBIOLOGY PROGRAM

Appendix B: Budget Summary

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The Astrobiology Program has one state-funded line (06-0439) administered by the Astronomy Department and controlled by the College of Arts & Sciences. The total amounts for the last three biennia were:

2005-07: $42K
2007-09: $44K
2009-11: $44K

This budget is used for graduate student and faculty travel to astrobiology conferences, small research needs of graduate students, public lectures, office expenses, partial summer salary for the Astrobiology Steering Group Chair, and general needs for the program (e.g., software, computer maintenance, Web and publication expenses).

Appendix C

Faculty active in the Astrobiology Program

[all are Full Professors on the Teaching faculty unless indicated otherwise]

Woodruff Sullivan (Astronomy)
Chair: Astrobiology Steering Group (members marked with *)
Homepage
Curriculum Vitae

Eric Agol (Astronomy, Assoc. Prof.)
Homepage

Joshua Bandfield (Earth & Space Sciences, Res. Asst. Prof.)
Short Biography
Curriculum Vitae (pdf download only)

John Baross (Oceanography)
Personal Profile

J. Michael Brown (Earth & Space Sciences)
Short Biography

Donald Brownlee (Astronomy)
Homepage

Adam Bruckner (Aeronautics & Astronautics)
Homepage
Brief CV (pdf download only)

*Roger Buick (Earth & Space Sciences)
Short Biography

*David Catling (Earth & Space Sciences, Assoc. Prof.)
Homepage
Publications

*Jody Deming (Oceanography)
Personal Profile
Publications

Alan Gillespie (Earth & Space Sciences)
Homepage

Deborah Kelley (Oceanography)
Personal Profile

John Leigh (Microbiology)
Faculty Profile
Community of Science Expertise Profile

*Victoria Meadows (Astronomy, Assoc. Prof.)
NASA Astrobiology Institute Profile

David Montgomery (Earth & Space Sciences)
Short Biography

Bruce Nelson (Earth & Space Sciences)
Short Biography

Thomas Quinn (Astronomy)
Homepage

*Peter Ward (Earth & Space Sciences/Biology)
Short Biography

Stephen Warren (Atmospheric Sciences/Earth & Space Sciences)
Atmospheric Sciences – Warren Group
Earth & Space Sciences Short Biography
List of Publications

Dale Winebrenner (Earth & Space Sciences, Res. Prof./Applied Physics Lab, Principal Physicist)
Earth & Space Sciences Short Biography
Applied Physics Lab Polar Science Center

Robert Winglee (Earth & Space Sciences)
Homepage
Curriculum Vitae (pdf download only)

Stephen Wood (Earth & Space Sciences, Res. Asst. Prof.)
Short Biography