Bioastronautics Education Workshop

June 19-20, 2017

Prof. David Klaus

University of Colorado
Boulder

Welcome to the University of Colorado College of Engineering and Applied Science!

New building just approved last week!

The Ann and HJ Smead

Department of Aerospace Engineering Sciences

http://www.colorado.edu/aerospace/2017/06/15/new-flagship-aerospace-facility-approved-cu-regents

Vision

- **To institutionalize Bioastronautics as an academic discipline**
  - Comprehensive curriculum framework established
  - Community of educators identified and organized

- With the nascent commercial space industry on the horizon, commercial crew vehicles under development and deep space exploration missions getting more firmly on government radars, now is time to formally establish Bioastronautics as a core pillar of academia
- Niche area, but growing student interest

A little historical perspective…

Dec 17, 1903 – Wright brothers' first flight at Kitty Hawk

April 12, 1961 – Gagarin makes first human space flight

August 7, 2018 will mark 57 years, 3 months and 26 days since the first human space flight and 114 years, 7 months and 21 days since the first human powered aircraft flight…

On Aug 7, 2018, human space flight will be half as old as powered air flight!

Workshop Agenda

Monday morning

- *0830-0900 Coffee / Check in / Networking*
- 0900-0915 Introductions and Workshop Objectives
- 0915-0945 Overview of CU Bioastronautics curriculum / Related Research / Student Placement
- 0945-1045 ~3-5 min summaries from each attendee – Teaching Interests / Research / Students
- 1045-1115 Break / refreshments / Group Photo
- 1115-1130 Textbooks and other information resources
- 1130-1200 Workshop Goals and Approach

Workshop Attendees

1	Allison Anderson	University of Colorado Boulder
2	Ana Diaz Artiles	Cornell University
3	Jay Buckey	The Geisel School of Medicine at Dartmouth
4	Torin Clark	University of Colorado Boulder
5	Kevin Crosby	Wisconsin Space Grant Consortium
6	Bonnie J. Dunbar	Texas A&M University
7	Reinhold Ewald	University of Stuttgart / ESA
8	Sathya Gangadharan	Embry-Riddle Aeronautical University, Florida
9	Dave Klaus	University of Colorado Boulder
10	Pedro Llanos	Embry-Riddle Aeronautical University, Florida
11	Jennifer Mindock	KBRwyle / NASA JSC
12	Jim Nabity	University of Colorado Boulder
13	Steve Robinson	University of California Davis
14	Mark Shelhamer	Johns Hopkins University
15	Jeff Smith	NASA KSC
16	Louis Stodieck	Univerity of Colorado Boulder / BioServe
17	Jim Voss	University of Colorado Boulder
18	Larry Young	MIT
19	Luis Zea	University of Colorado Boulder / BioServe

Bioastronautics Education Workshop, University of Colorado Boulder, June 19-20, 2017

Interested in participating, but unable to attend

1	Angel Abbud-Madrid	Colorado School of Mines
2	Kira Abercromby	Cal Poly SLO
3	Dave Akin	Univ. Maryland
4	Chantal Cappelletti	National University of Brasilia
5	James Casler	University of North Dakota
6	Greg Chamitoff	Texas A&M University
7	Jonathan Clark	Baylor College of Medicine
8	Markus Czupalla	Univ. Aachen
9	Pablo de León	University of North Dakota
10	Olivier de Weck	MIT
11	Kevin Duda	Draper
12	Pedro Duque	ESA
13	Christer Fuglesang	Swedish KTH Royal Institute of Tech
14	Robert Gitten	University of Michigan
15	Judith Hayes	NASA JSC
16	Rick Hieb	University of Colorado Boulder
17	Jeff Hoffman	MIT
18	Brad Holschuh	University of Minnesota
19	Ryan Kobrick	Embry-Riddle Aeronautical Univ, Florida
20	Wendy Lawrence	American Military University

Interested in participating, but unable to attend

21	Kris Lehnhardt	George Washington University
22	Ed Mango	
23	Karina Marshall-Goebel	Harvard Med School / Mass Gen Hospital
24	Barbara Morgan	Boise State University
25	Dava Newman	MIT
26	Claude Nicollier	Swiss Federal Institute of Technology, Lausanne
27	Samuel Nuzbrokh	University of Michigan
28	Chuck Oman	MIT
29	Jim Pawelczyk	Penn State
30	Gary Payton	U.S. Air Force Academy
31	Imara Perera	NCSU
32	Ed Powers	University of Texas Medical Branch Galveston
33	Ken Reightler	U.S. Naval Academy
34	Leia Stirling	MIT
35	Jeff Sutton	Baylor College of Medicine, Center for Space Medicine
36	Steve Swanson	Boise State University
37	Kathy Thornton	University of Virginia
38	Jim Vanderploeg	University of Texas Medical Branch Galveston
39	Ulrich Walter	Technical University of Munich

Workshop Purpose

- The purpose this workshop is to identify ‘who is teaching what’ and use that as a starting point to formulate a comprehensive Bioastronautics curriculum, along with outlining specific course lecture content and associated learning objectives
- The workshop outcome will be to define a draft set of curriculum standards that can be used to establish any variety of specialized courses at the different schools with some consistency and to open up lines of communication between those of us teaching this material

Some background…

- The term *bioastronautics* elegantly captures the essence of this broad academic discipline and is showing up at a growing number of institutions as this novel field of study matures and becomes more commonplace.
- Especially now, with the onset of the commercial space industry, it is timely to begin systematically standardizing learning objectives and developing effective course structures that will serve the needs of future human spaceflight educators in different fields under the collective heading of bioastronautics.

Some background…

- From a literature search, the term ‘bioastronautics’ appears to have first come into use in the late 1950’s as the push for sending humans into space began in earnest.

Taylor, E. R. (1958) Physical and physiological data for bioastronautics, USAF School of Aerospace Medicine, Aviation Medicine Special Report, Randolph AFB, TX, USA

Rowen, B. (1961) Bioastronautics Support of the X-15 Program (No. TDR61 61). Air Force Flight Test Center, Edwards AFB CA

Gerathewohl S.J. (1963) Principles of Bioastronautics. Englewood Cliffs, NJ, USA: Prentice-Hall

Rowen, L. C. B. (1963) Dyna-Soar Bioastronautics. USAF, School of Aerospace Medicine

Bedwell Jr, T.C., and Strughold, H. (1965) Bioastronautics and the Exploration of Space. Southwest Research Institute, San Antonio, TX

Roadman, C. H., Strughold, H., Mitchell, R. B., Harmon, J., & Schafer, R. (1968) Bioastronautics and the Exploration of Space. Aerospace Medical Division, Brooks AFB TX

- Beyond these historical roots, however, the term seemingly dropped from general use in the subsequent few decades, but was reinvigorated throughout the NASA community again in the early 2000’s.

Some background…

- As noted in NASA's *Bioastronautics Data Book* foreword "*This volume fulfills a basic requirement of the engineer for quantitative and qualitative human data upon which to develop design criteria*." (Webb* 1964)
  - An earlier version was published as a pilot study titled *NASA Space Life Sciences Data Book* (Webb* 1962)
  - A second edition *(Big Red Book!)* of the *Bioastronautics Data Book* captured the subsequent technological progress and advances in life sciences made during the 1960's as the Apollo Program unfolded. (Parker and West 1973).

** The AIAA Jeffries Aerospace Medicine and Life Sciences Research Award was awarded to Dr. Paul Webb in July 2014, he passed away shortly before receiving it.*

https://www.aiaa.org/HonorsAndAwardsRecipientsList.aspx?awardId=481d0fc9-2536-4d04-b2a2-f69f1d56c3d7

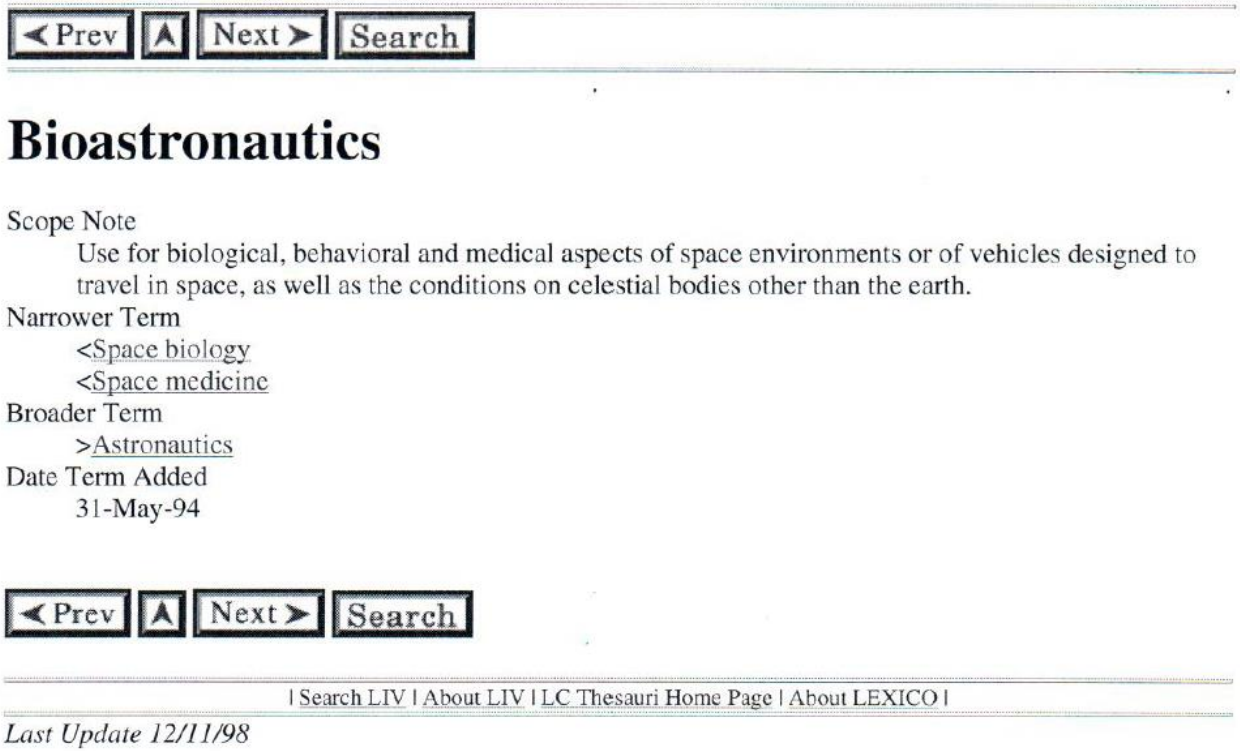
Some background…

- We formally adopted the term *Bioastronautics* at CU in the fall of 2000 as the name of a new aerospace graduate focus area that had evolved from an existing space habitat and space life sciences-based curriculum taught here since the mid-1980s

Luttges, M.W., Stodieck, L. and Klaus, D.M. (1994) Four Educational Programs in Space Life Sciences. Advances in Space Research 14(8): 439-446

Some background…

- *I came across a definition (and fortunately printed it interestingly on Yuri's day April 12, 2000!) on this now defunct library of congress URL dated May 31, 1994 (updated 12/11/98)*



◄Prev ▲ Next► Search

Bioastronautics

Scope Note
Use for biological, behavioral and medical aspects of space environments or of vehicles designed to travel in space, as well as the conditions on celestial bodies other than the earth.
Narrower Term
<Space biology
<Space medicine
Broader Term
>Astronautics
Date Term Added
31-May-94

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Last Update 12/11/98

(http://www.loc.gov/lexico/liv/b/Bioastronautics.html)

Some background…

We modified the definition to read as follows:

- **Bioastronautics encompasses biological, behavioral and medical aspects governing humans and other living organisms in a space flight environment; and includes design of payloads, spacecraft habitats, and life support systems.**

- In short, Bioastronautics spans the *study* and *support* of life in space.

Some background…

Encyclopedia of Bioastronautics [article in prep]

Section: **Graduate Programs in Bioastronautics**

- *Definition*: This section proposes a pedagogical framework for establishing a comprehensive curriculum that incorporates bioastronautics – *the study and support of life in space* – into graduate education and also introduces an overview of currently identified educational programs that offer coursework or research programs in various topics related to this field of study.

Going forward

- **Bioastronautics** – solidify definition and incorporate discipline into academia

- **Curriculum** – from workshop outcome, I will edit and post the material for dissemination and review

- **Community** – continue to add others who are teaching bioastronautics as they are identified, I'll post the list for ongoing upkeep and visibility, we'll discuss ideas for how to use this information later

Workshop Objectives

- Determine consensus on short academic definition of ‘Bioastronautics’ as *the study and support of life in space*

- Identify lecture topics and learning objectives across different categories and courses within disciplines of engineering, science, medicine, and other areas

- Establish a network of Bioastronautics Educators

Overview of CU Bioastronautics MS Degree Plan

MS Aerospace Engineering Sciences, Bioastronautics Focus
(*10 courses, 30 credit hours*)

1 **Space Life Sciences** http://www.colorado.edu/bioastronautics/curriculum
2 **Space Habitat Design**

3,4 **Grad Projects** or **MS Thesis** (*2 semesters*), or **Certificate** (*variable*)
5 Math

6,7, (8) **Orbital Mechanics**, **Rocket Propulsion**, **Space Environment**
(*min 2 of 3 required*)

(8) 9, 10 **Technical Electives** or **Independent Study** (or **Certificate**)

http://www.colorado.edu/aerospace/current-students/graduates/curriculum/bioastronautics

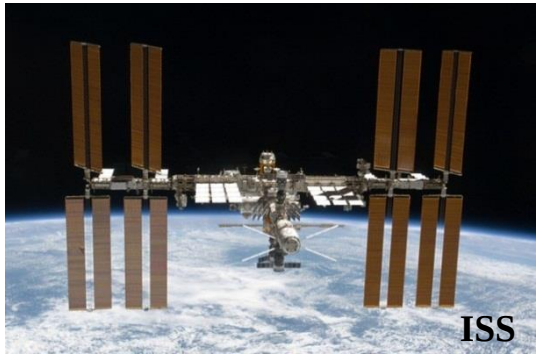
Overview of CU Bioastronautics Related Research Areas

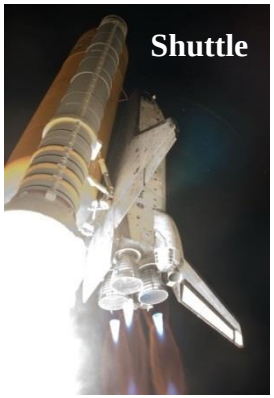
http://www.colorado.edu/bioastronautics/research

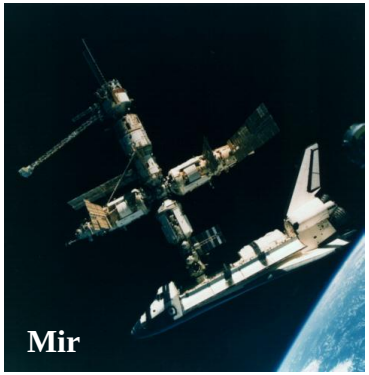
- FAA Center of Excellence for Commercial Space Transportation
- Human-rating and Risk Analysis
- ECLSS low TRL technology feasibility evaluation
  - thermal control, atmosphere revitalization, waste management, radiation mitigation, spacesuit components
- Habitat / EVA Systems Design
- Human Performance Evaluation
- Human Factors / Human Centered Design
- Neurovestibular Research
- BioServe Space Technologies – space biotechnology

BioServe Space Technologies

Payload Spaceflight History







1. STS-37	Apr 1991	29. STS-123 (*ISS*)	Mar 2008
2. STS-43	Aug 1991	30. STS-124 (*ISS*)	May 2008
3. STS-50	Jun 1992	31. STS-126 (*ISS*)	Nov 2008
4. STS-54	Jan 1993	32. STS-119 (*ISS*)	Mar 2009
5. STS-57	Jun 1993	33. STS-125 (*HST*)	May 2009
6. STS-60	Feb 1994	34. STS-128 (*ISS*)	Aug 2009
7. STS-62	Mar 1994	35. STS-129 (*ISS*)	Nov 2009
8. STS-63	Feb 1995	36. STS-130 (*ISS*)	Feb 2010
9. STS-69	Sep 1995	37. STS-131 (*ISS*)	Apr 2010
10. STS-73	Oct 1995	38. STS-132 (*ISS*)	May 2010
11. STS-77	May 1996	39. STS-133 (*ISS*)	Feb 2011
12. STS-79 (*NASA/Mir 3*)	Sep 1996	40. STS-134 (*ISS*)	May 2011
13. STS-83	Apr 1997	41. STS-135 (*ISS*)	July 2011
14. STS-94	Jul 1997	42. HTV-3 (*ISS*)	July 2012
15. STS-86 (*NASA/Mir 6*)	Sep 1997	43. Dragon / SpaceX-1 (*ISS*)	Oct 2012
16. STS-95	Oct 1998	44. Dragon / SpaceX-2 (*ISS*)	Mar 2013
17. STS-93	Jul 1999	45. Cygnus / Orbital-1 (*ISS*)	Jan 2014
18. STS-106	Sep 2000	46. Dragon / SpaceX-3 (*ISS*)	Apr 2014
19. STS-100 (*ISS*)	Apr 2001	47. Dragon / SpaceX-4 (*ISS*)	Sep 2014
20. STS-108	Dec 2001	48. Dragon / SpaceX-5 (*ISS*)	Jan 2015
21. STS-110 (*ISS*)	Apr 2002	49. Dragon / SpaceX-6 (*ISS*)	Apr 2015
22. STS-112 (*ISS*)	Oct 2002	50. Cygnus / OA-4 (*ISS*)	Dec 2015
23. STS-107 (*Columbia*)	Jan 2003	51. Dragon / SpaceX-8 (*ISS*)	Apr 2016
24. Progress 13-P (*ISS*)	Jan 2004	52. Dragon / SpaceX-9 (*ISS*)	July 2016
25. STS-115	Sep 2006	53. Cygnus / OA-5 (*ISS*)	Oct 2016
26. STS-116 (*ISS*)	Dec 2006	54. Dragon / SpaceX-10 (*ISS*)	Feb 2017
27. STS-118 (*ISS*)	Aug 2007	55. Dragon / SpaceX-11 (ISS)	Jun 2017
28. Soyuz 15-S (*ISS*)	Oct 2007		

Overview of CU Bioastronautics Student Placement

- NASA - JSC, KSC and Ames
- Lockheed Martin
- Boeing
- SpaceX
- Blue Origin
- Sierra Nevada
- Orbital ATK
- Bigelow Aerospace
- David Clark Co.
- BioServe
- KBRwyle
- UTAS
- ULA
- Paragon
- World View
- Academia
- Entrepreneurial Startup
- Military
- Med School
- Grad School
- Peace Corps

Bioastronautics-related Student Design Competitions

- **CalTech Space Challenge**
  http://www.spacechallenge.caltech.edu/
- **MIT/Skoltech Space Exploration Strategy University Research Group**
  http://spacestrategy.mit.edu/
- **NASA's eXploration Habitat (X-Hab) Academic Innovation Challenge**
  http://www.nasa.gov/exploration/technology/deep_space_habitat/xhab/
- **NASA/NIA Revolutionary Aerospace Systems Concepts-Academic Linkage (RASC-AL)** -
  http://rascal.nianet.org/
- **NASA Space Radiation Summer School, Brookhaven National Laboratory**
  http://spaceradiation.jsc.nasa.gov/nsrss/2015/
- **Space Horizons Workshop, Brown University**
  https://spacehorizonsworkshops.wordpress.com/
- **University of Stuttgart Space Station Design Workshop**
  http://www.irs.uni-stuttgart.de/SSDW
- **ESA Academy**
  http://www.esa.int/Education/ESA_Academy

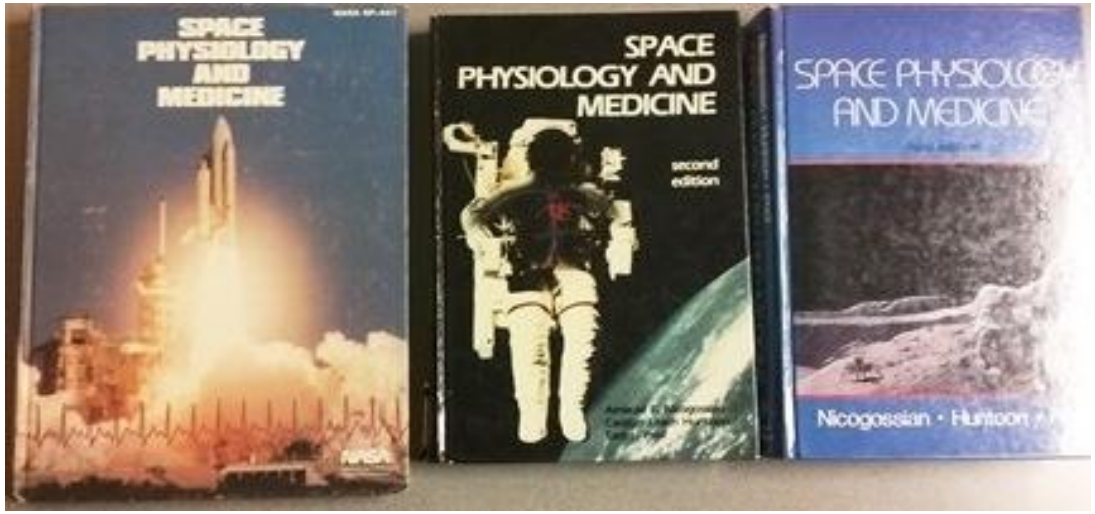
~3-5 min summaries from attendees

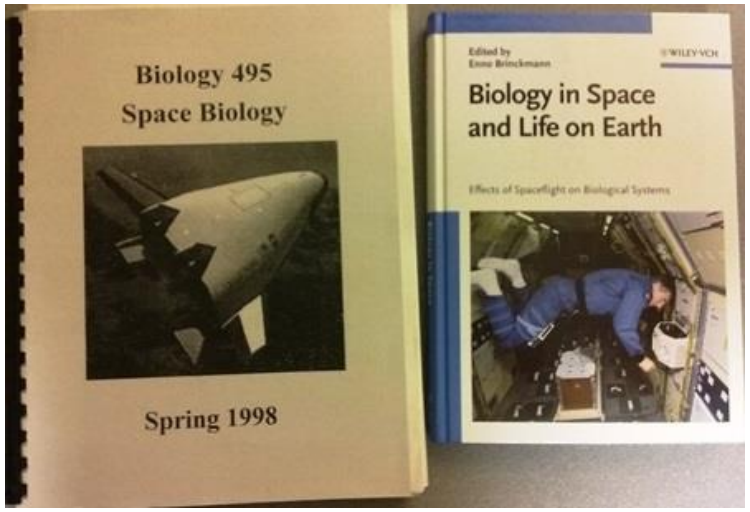
- Teaching Interests / Courses Offered
- Related Research Program
- Student Involvement / Placement

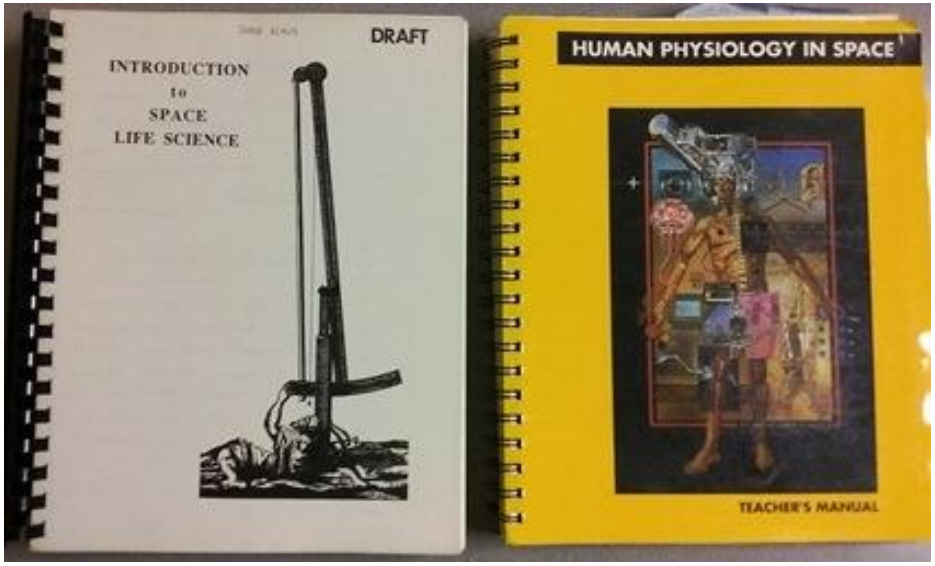
Also, do you know of any other programs not represented here?

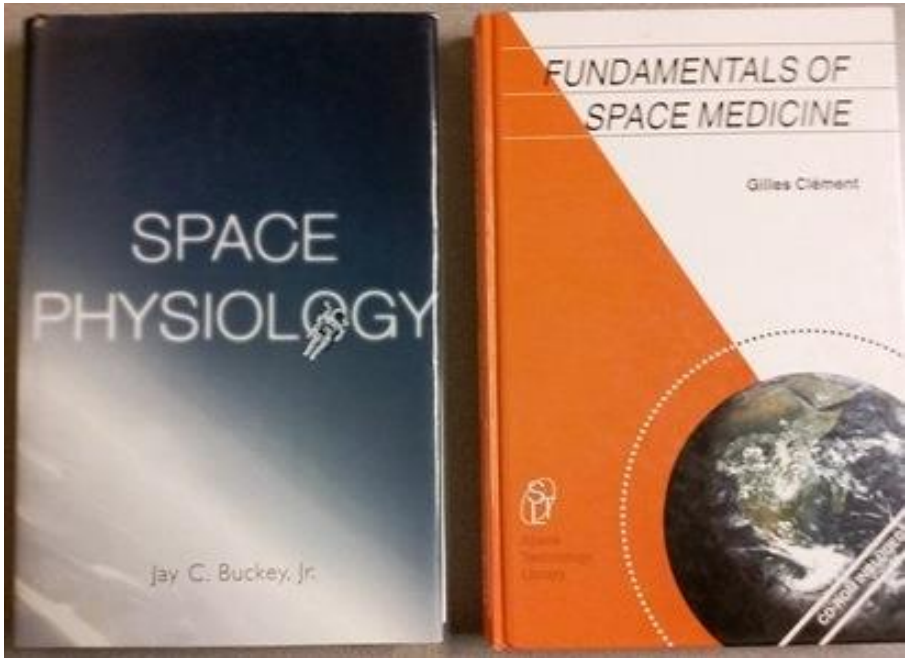
Textbooks *currently used at CU*
(*see others on table and in info sent by email*)

- **Spacefaring - The Human Dimension**, Harrison, A., University of California Press, Los Angeles, CA, 2001
  - **ASEN 3036 Intro to Human Space Flight**
- **Space Physiology**, Buckey, Oxford University Press, 2006
  - **ASEN 5016 Space Life Sciences**
- **Human Spaceflight Mission Analysis and Design**, eds. Larson and Pranke, McGraw-Hill, 2007
  - **ASEN 5158 Space Habitat Design**
- **Spaceflight Life Support and Biospherics**, Eckart, P, Space Technology Library, Microcosm Press, 1994
  - **ASEN 6116 Spacecraft Life Support Systems**

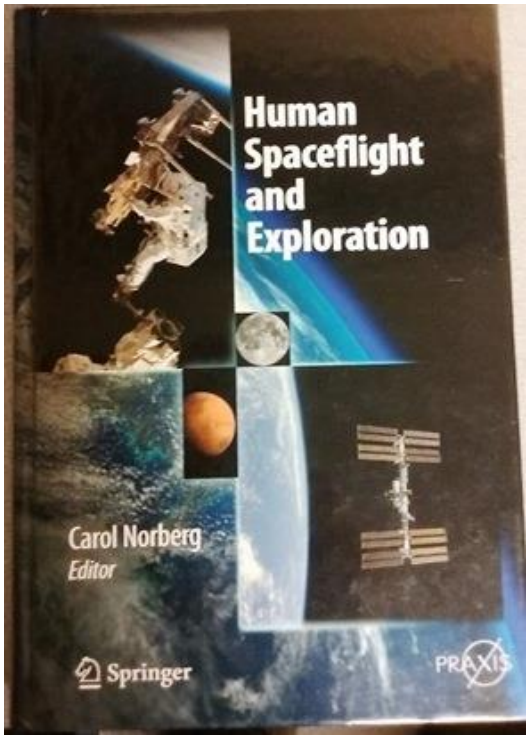

SPACE PHYSIOLOGY AND MEDICINE
SPACE PHYSIOLOGY AND MEDICINE
second edition
SPACE PHYSIOLOGY AND MEDICINE
Nicogossian • Huntoon

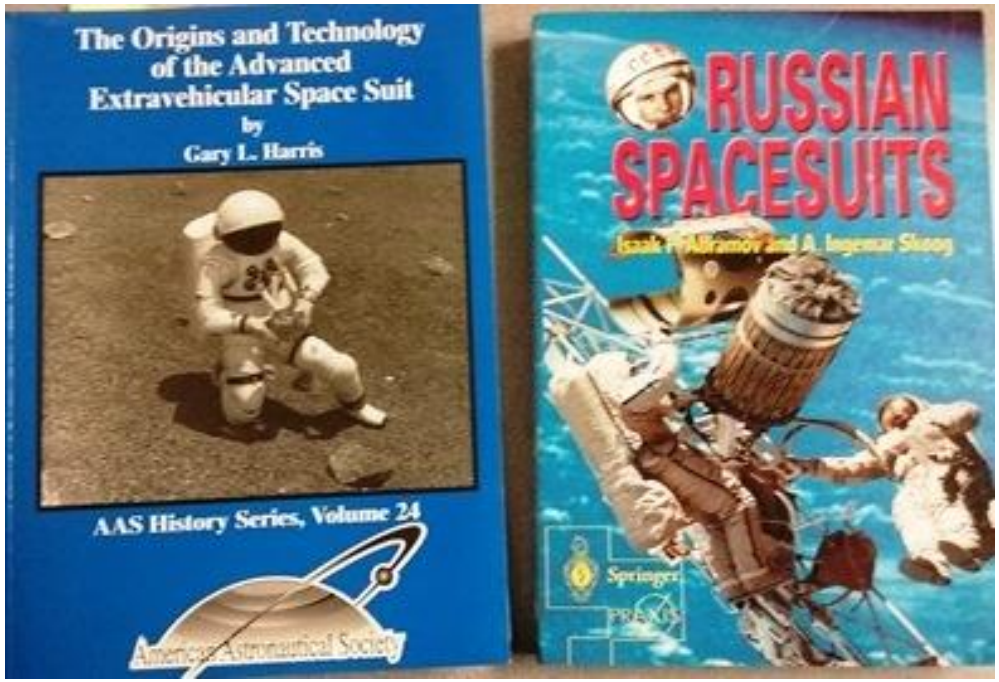

Biology 495
Space Biology
Spring 1998
Edited by
Enno Brinckmann
Biology in Space and Life on Earth
Effects of Spaceflight on Biological Systems

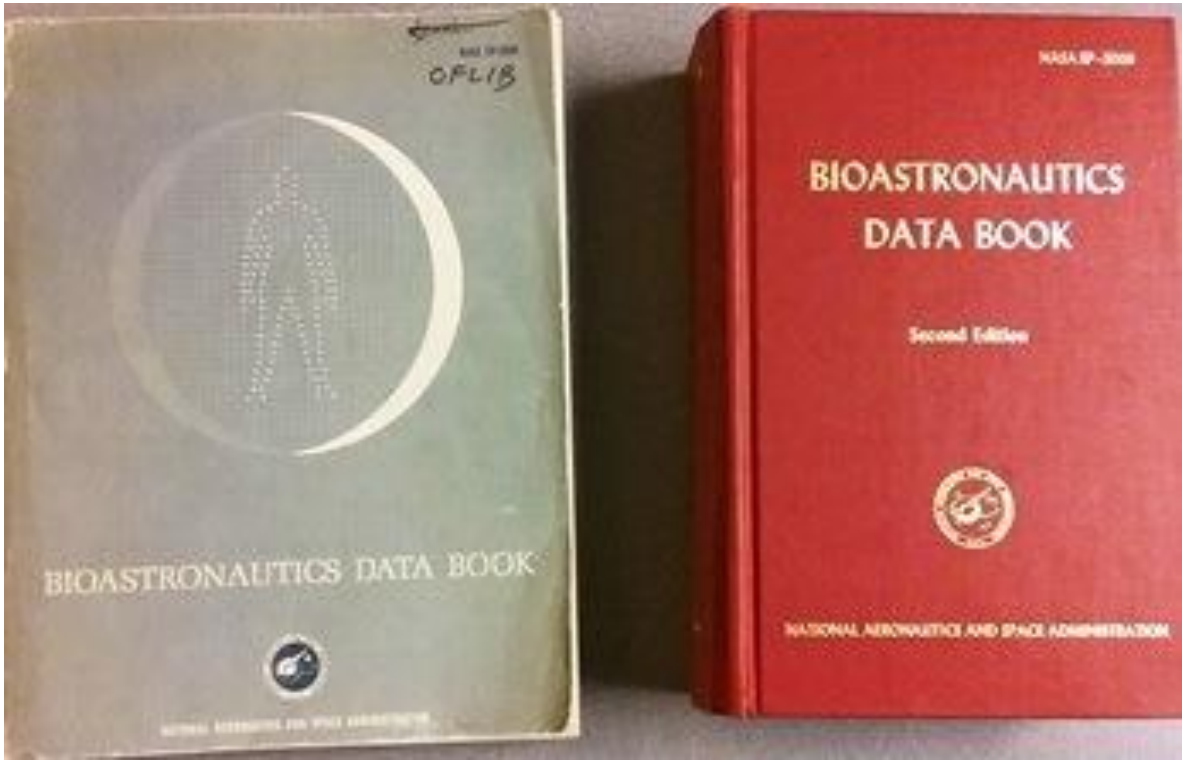

DRAFT
INTRODUCTION to SPACE LIFE SCIENCE
HUMAN PHYSIOLOGY IN SPACE
TEACHER'S MANUAL

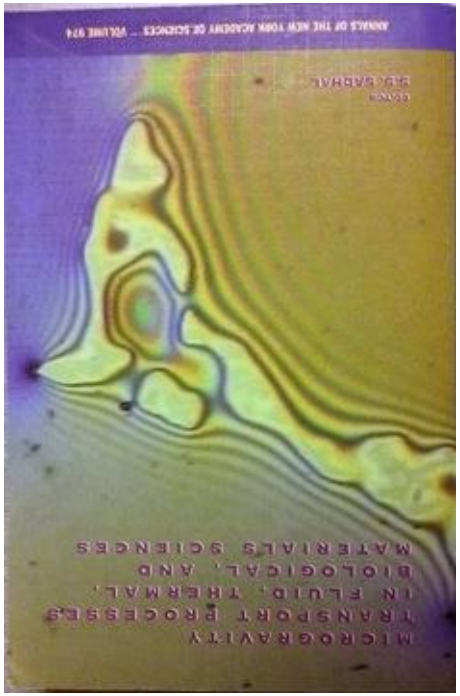

SPACE PHYSIOLOGY
Jay C. Buckey, Jr.
FUNDAMENTALS OF SPACE MEDICINE
Gilles Clément

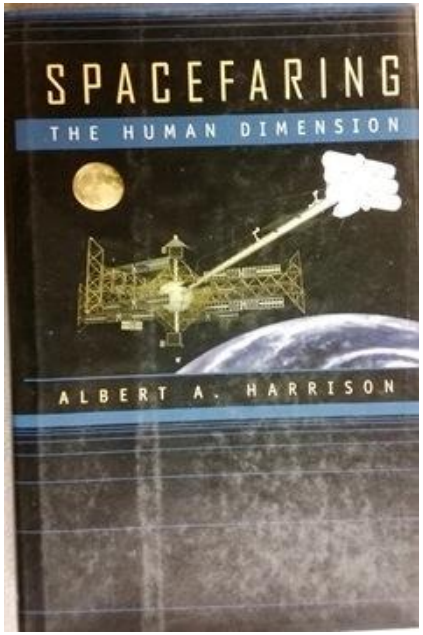

SPACEFLIGHT
LIFE SUPPORT
AND BIOSPHERICS
Peter Eckart
Space Technology Library
Human
Spaceflight
MISSION ANALYSIS AND DESIGN


Human
Spaceflight
and
Exploration
Carol Norberg
Editor
Springer
PRAXIS


The Origins and Technology
of the Advanced
Extravehicular Space Suit
by
Gary L. Harris
AAS History Series, Volume 24
American Astronautical Society
RUSSIAN
SPACESUITS
Springer
PRAXIS


OFLIB
BIOASTRONAUTICS DATA BOOK
NASA SP-3008
BIOASTRONAUTICS
DATA BOOK
Second Edition
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION


MICROGRAVITY
TRANSPORT PROCESSES
IN FLUID, THERMAL,
BIOLOGICAL, AND
MATERIALS SCIENCES


SPACEFARING
THE HUMAN DIMENSION
ALBERT A. HARRISON

Starting with our (CU) current definition

- **Bioastronautics encompasses biological, behavioral and medical aspects governing humans and other living organisms in a space flight environment; and includes design of payloads, spacecraft habitats, and life support systems.**

- In short, Bioastronautics spans the *study* and *support* of life in space.

Terminology Hierarchy

- **Broad Categories** – *design, science, policy, etc.*
- **Specific Courses** – *subset of material within a category*
- **Lecture Topics** – *grouped into a select course*
- **Learning Objectives** – *important aspects of a topic*

Categories

1. **Space Program / History / Policy / Operations**
2. **Space Habitat & Spacesuit Design**
3. **Space Life Sciences**
4. **Microgravity Sciences**
5. **Other?**

Lecture Topics

- **Lecture topics are grouped into desired syllabus**
- **Broad survey courses vs. in depth topic focus**
  - Some topics can be in multiple categories
  - A topic can have differing levels of learning objectives
  - Almost any single lecture can be an entire class
- **One lecture Topic in Space Habitat Design is ECLSS**
  - Basic functional concepts for air, water, food and waste
- **ECLSS is also an entire semester class**
  - Detailed technology processes described
  - Hands on lab demonstrations

Learning Objectives
(*from Bloom's Taxonomy increasing levels 1-6*)

1. **Knowledge**: list, recite, identify, outline
2. **Comprehension**: explain, paraphrase, describe, interpret, distinguish
3. **Application**: apply, calculate, determine, solve
4. **Analysis**: classify, predict, derive, interpret
5. **Synthesis**: propose, formulate, design, create
6. **Evaluation**: judge, select, determine, optimize, critique, justify

Learning Objectives

- A good objective begins with an action word
  - The student will be able to…
  - Measurable outcome
  - Allows evaluation per specific expectations
  - Typically 3-5 per lecture topic
  - Helps keep lecture focused
- Avoid use of ‘non-instructional’ objectives that are desired, but not directly observable
  - Know, learn, appreciate, understand

Workshop Goals and Approach

- **Produce a comprehensive set of categories, courses, lecture topics and learning objectives**
  - Outcome will be a draft ‘a la carte’ menu of lecture topics with accompanying learning objectives organized by category, reviewed and disseminated
- **Identify other institutions / individuals not represented here who teach classes in this area**
  - Outcome will be a list of schools / faculty with courses offered in bioastronautics
- **Discuss next steps**
  - Any follow on plans desired

Workshop Agenda

Monday afternoon

- 1200-1245 Lunch (*will be provided on site*)
- 1245-1300 Break
- 1300-1530 Split into working groups to identify courses / learning objectives in each of the various categories (policy/operations, space habitat/spacesuit design, physiology/biology, research, etc.)
- 1530-1630 Lab tours (Bioastronautics and BioServe)
- 1630-1700 Wrap up for the day / plans for tomorrow

Monday evening – dinner 6:15 pm at The Med

https://www.themedboulder.com/

Splinter Groups Facilitators

- Jim Voss
  - **Space Program / History / Policy / Operations**
- Torin Clark
  - **Space Habitat & Spacesuit Design**
- Allie Anderson
  - **Space Life Sciences**
- Jim Nabity
  - **Microgravity Sciences**
- Other?

Brainstorming time!


OTHER

Workshop Agenda

Tuesday morning

- *0830-0900 Coffee / Networking*
- 0900-0915 Recap of plans for the day
- 0915-1000 Splinter groups reconvene / prep outcome summary
  1000-1015 Break / refreshments
- 1015-1115 Summaries from splinter group reps – categories/courses/lecture topics/learning objectives
- 1115-1200 Wrap up / Decide on next steps… Periodic meetings? Organize as a group? Other ideas?

Tuesday noon – adjourn

Tuesday afternoon – *open for lunch and continued conversation*

Suggestions for working definition edited from group discussion…

- **Bioastronautics encompasses the biological, behavioral and medical sciences of space exploration; and includes the design and engineering of missions, payloads, habitats, and life support systems.**
- In short, Bioastronautics spans the *study* and *support* of life in space.

[Alternative wording]

By Laurence R. Young
For submission as article 1 in the Encyclopedia of Bioastronautics: (Subtitle – Why Risk Humans for Space Exploration)
Version 3, Sept 29, 2015

Definition: Bioastronautics is the intersection of space science and technology with biology and human factors. It encompasses both human and non-human space life science, including astronaut performance, protection and life support as well as the effect of space on biological processes.

Splinter Group Summaries

- **List of Categories**
- **List of Courses**
- **Discussion of Topics (no need to list all)**
- **Ideas for Learning Objective formulation**

Splinter Group Summaries

1. **Space Program / History / Policy / Operations**
2. **Space Habitat & Spacesuit Design**
3. **Space Life Sciences**
4. **Microgravity Sciences**
5. **Other?**

Summary of outcomes being compiled for dissemination, coming soon…

Wrap up and Next Steps

- Online resources / webpage – *DK will set up a template to start getting relevant info organized (list of schools, faculty, syllabi, resources, student opportunities, conferences, etc.)*
- Certificate option
- Bioastronautics Textbook
- Team teaching
- Course material sharing – lecture, exams, homework
- Future meetings – *suggested for next year: present course summaries from each school, invite stakeholders from industry and government for input, add video connection for distance participation, DK to coordinate, location TBD, volunteers?*
- Society of Bioastronautics Educators – *thoughts?*

- Other ideas / discussion… – *Ana to explore ties with ISU*

The Beginning