Department of Aeronautics and Astronautics
School of Engineering
Massachusetts Institute of Technology

Graduate Program (S.M., Ph.D., Sc.D.)

Field: Humans in Aerospace
Date: September 4, 2007

1. Introduction and Purpose

The graduate program in the Department of Aeronautics and Astronautics at M.I.T. provides educational opportunities in a wide variety of aerospace-related topics through academic subjects and research. The purpose of this document is to provide incoming masters and doctoral level students guidance in planning the subjects they will take during their graduate program. The suggestions outlined here are to be understood as guidance and not as a mandatory, rigid framework. The final decision as to which subjects are taken and in what sequence is to be decided between each student and their academic advisor and/or doctoral committee. In addition to these recommendations, the official S.M. and doctoral degree completion requirements must be taken into account during the design of a graduate program[1].

2. Motivation for studying Humans in Aerospace

Ever since the Wright Brothers (1903) managed to keep their flyer aloft, despite severe control challenges, it has been apparent that flying machines could not be designed without explicit consideration of human operators. Even recent unmanned areal vehicles (UAVs) require operators on the ground to program, remotely control, and monitor airborne operations from a distance. The study of human factors in aerospace covers the efficiency, safety and comfort of pilots, passengers and controllers. More recently, the safety, comfort and effectiveness of astronauts have also been shown to be significantly impacted by factors such as equipment (space suits, tools), operating environment as well as established operating procedures. A through understanding of the interplay of these human factors is essential to ensure future mission success in the air and in space.

3. What comprises the study of Humans in Aerospace?

The air and space environments present significant challenges to the human body and mind. In particular, the acceleration, atmosphere, and radiation environments are of special concern to the well being of pilots and astronauts. The complex interactions between humans and machines, including a high degree of automation in aerospace

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[1] Refer to the S.M., Ph.D. and Sc.D. degree requirements in Aeronautics and Astronautics section of the MIT Bulletin, or to http://web.mit.edu/aeroastro/academics/grad/index.html

systems, is another major consideration for these complex sociotechnical systems. The study of humans in aerospace at MIT specializes in three areas:

<u>Humans and Automation</u>: Understanding cognitive workload and the degree to which automation (software, displays, controls and algorithms) can assist humans in more effectively and efficiently operating and supervising aerospace vehicles, while maintaining appropriate levels of workload, safety and system awareness.

<u>Physiology of Humans in Aerospace</u>: Understanding how specific operating conditions in aerospace environments affect the health, comfort and efficiency of human operators and passengers. This area encompasses the study of human visual perception, orientation, the effects of weightlessness and partial gravity on the human physiology as well as specialized effects such as spatial disorientation. Applications include life support systems and crew protective devices, ranging from ejection seats to EVA suits.

<u>Human Factors in System Design</u>: This area of research includes the design of displays and controls for human interaction with complex systems, pilot and astronaut suits and support equipment as well as the design of various aids for system status monitoring, crew coordination, communications, manual control, and overall system safety.
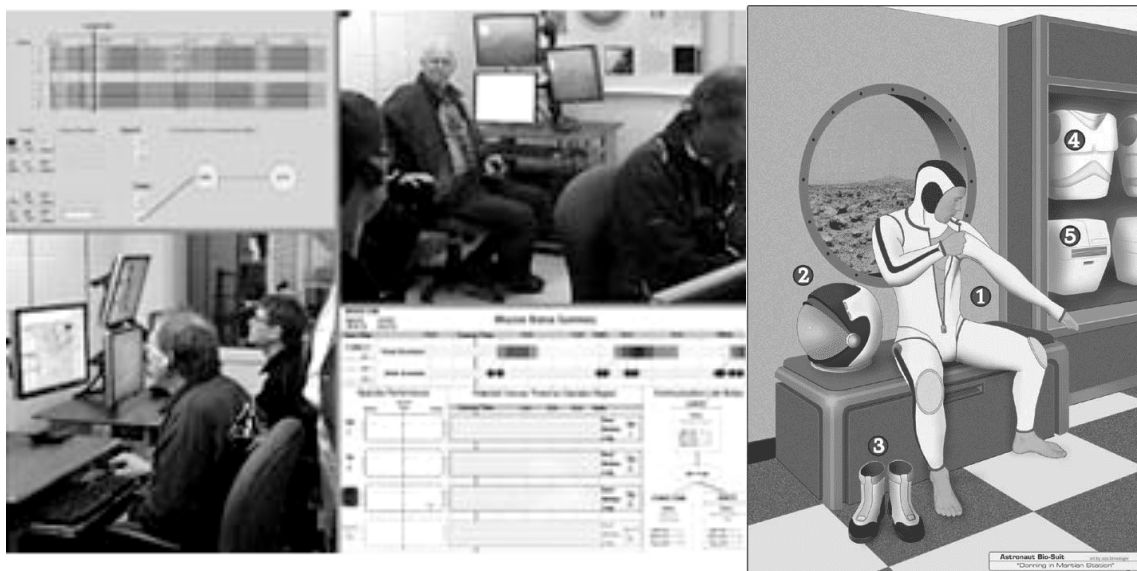

Figure 1: (left) remote operation of aerospace systems, (right) astronaut space suit design

4. Educational Goals for Humans in Aerospace

The overall educational goal of the MIT graduate program in Humans in Aerospace is to provide students with an understanding of the functioning of human psychology and physiology and the interactions with aerospace systems and environments. Students should develop a thorough understanding of the integration of humans in aerospace

systems. This integration encompasses human-machine interactions and the nature of human error.

Successful graduates of the program will have achieved the following specific learning objectives:

- They will have acquired the ability to prescribe requirements and constraints on aerospace vehicles related to human comfort, effectiveness and safety.

- They will have gained an understanding of those aspects of human psychology and physiology which relate to the design and operation of aerospace systems.

- They will be able to analyze aerospace accidents with a focus on human factors causes and contributing factors, and suggest design alternatives for both aviation and space systems.

- They will be able to directly contribute to the design of new space exploration vehicles, life support systems, and remote habitats, as well as to the redesign of existing systems.

- They will be able to design and evaluate cockpit and controller stations for advanced aircraft and for the control of mixed fleets of manned or unmanned vehicles.

- They will have exercised this knowledge for the design of a particular air or space mission in the context of a multi-disciplinary team.

- They will have generated research contributions to the current humans in aerospace body of knowledge

To achieve these goals, each student should develop an educational plan with their academic advisor and/or doctoral committee following the guidelines outlined below.

5. Educational Plan for Humans in Aerospace

Students interested in Humans in Aerospace may enter the program with little or no background in life sciences, but with a strong engineering preparation and a desire to work at the intersection between aerospace engineering and life sciences. They must be prepared to learn the "foreign languages" of psychology and physiology, and to apply their learning to aerospace issues.

Entering students typically take the initial Header Course 16.453J (Human Factors Engineering) in their first Fall term, to get an overview of Human Factors as well as to gain familiarity with its application to real case studies in aviation and space accidents. For those students focusing on Physiology, in the alternate Springs when 16.423J

(Aerospace Biomedical and Life Support Engineering) is offered, that subject should normally be taken..

Students interested more in Human Factors and the psychology of human-machine interaction which includes cognitive engineering, workload measurement, human performance modeling interfaces with automation and unmanned vehicles, etc., are advised to continue with 16.422 (Human Supervisory Control of Automated Systems) and other related autonomy and decision making courses.

Students whose interests lie in the direction of aereospace biomedical engineering are advised to pursue 16.430J (Sensory-Neural Systems) or any of the first level subjects in physiology offered by the Division of Health Sciences and Technology (HST). They are also advised to take 16.459 (Bioengineering Journal Article Seminar) a 2 unit subject which can be taken for credit up to three times, and which provides practice in critical reading and presentation of current research in the field of Humans in Aerospace. The subjects and research for the aerospace biomedical aspects of Humans in Aerospace are closely allied to the Bioastronautics Ph.D. Program, which is part of the Medical Engineering and Medical Physics Program in the Harvard-MIT Division of Health Sciences and Technology (hst.mit.edu/bioastronautrics). Separate application to HST is required for that program.

Additionally all students have to meet the departmental Mathematics Requirement with two graduate level mathematics courses. Students interested in Humans and Aerospace are strongly advised to take at least one course in probability and statistics (e.g. 16.470, Statistical Methods in Experimental Design) as part of the mathematics preparation. The department keeps a list of mathematics courses that are acceptable for fulfillment of this requirement.

A graduate capstone design subject, either 16.89J (Space Systems Engineering) or 16.885J (Aircraft Systems Engineering) is strongly recommended.

Thesis research for Humans in Aerospace is generally conducted in one of three departmental laboratories: The Man-Vehicle Laboratory (MVL), which has close ties to the Volpe Transportation Research Center and the National Space Biomedical Research Institute, emphasizes human aerospace physiology and perception. The Humans and Automation Laboratory (HAL), with ties to the military and international industrial aviation communities, specializes in human-centered design principles applied to human-computer optimization. The International Center for Air Transportation (ICAT) applies information technology to improving the safety and effectiveness of air transportation.

6. Courses related to Humans in Aerospace

The <u>header course</u> is:

16.453   Human Factors Engineering

Additional <u>follow-on</u> are:

16.423	Aerospace Biomedical and Life Support Engineering
16.422	Human Supervisory Control of Automated Systems
16.459	Bioengineering Journal Seminar
16.89	Space Systems Engineering
16.885	Aircraft Systems Engineering
16.470	Statistical Methods in Experimental Design

Other recommended <u>electives</u> are:

16.430	Sensory-Neural Systems
HST.560J	Radiation Biophysics
HST.921J	Information Technology in the Health Care System of the Future
HST.971J	Biomedical Enterprise
16.346	Astrodynamics
16.31	Feedback Control
16.413	Principles of Autonomy and Decision Making
16.862	Engineering Risk-Benefit Analysis
16.863J	System Safety
16.888	Multidisciplinary System Design Optimization
16.895J	Engineering Apollo: The Moon Project as a Complex System
ESD.33	Systems Engineering

Suggested <u>mathematics courses</u> are:

16.470	Statistical Methods in Experimental Design
18.85	Mathematical Methods for Engineers I
18.443	Statistics for Applications
16.060 (U), 18.700	Linear Algebra

7. Faculty and Staff with Interests in Humans in Aerospace

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Please consult the MIT Aero & Astro web-page for detailed faculty and staff interests:
http://web.mit.edu/aeroastro/faculty/faculty.html