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Life-sciences research opportunities in commercial suborbital space flight

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ABSTRACT

Commercial suborbital space flights will reach altitudes above 100 km, with 3–5 min of weightlessness bracketed by high-g launch and landing phases. The proposed frequency of these flights, and the large passenger population, present interesting opportunities for researchers in the life sciences. The characteristics of suborbital flight are between those of parabolic and orbital flights, opening up new scientific possibilities and easing the burden for obtaining access to 0*g*.

There are several areas where these flights might be used for research in the life sciences: (1) operational research: preparation for "real" space flight, such as rehearsal of medical procedures, (2) applied research—to answer questions relevant to long-term space flight; (3) passenger health and safety—effects on passengers, relevant to screening and training; (4) basic research in physiological mechanisms—to address issues of fundamental science.

We describe possible projects in each of these categories. One in particular spans several areas. Based on the anticipated suborbital flight profiles, observations from parabolic flight, and the wide range of fitness and experience levels of suborbital passengers, sensorimotor disturbances such as motion sickness and disorientation are major concerns. Protocols for pre-flight adaptation of sensorimotor responses might help to alleviate some of these problems, based on results from research in the initial flights. This would improve the passenger experience and add to the knowledge base relevant to space flight more generally.

1. Introduction

We have been exploring space via flights with humans for over 50 years. In that time a great many things have been learned about the environment of space and how to perform useful work in that environment. We have also learned much about how the human body responds to the stresses of space flight, and in some cases how to improve those responses to maintain health and sustain performance. Despite great progress during this time, there is much that remains to be learned about the human response to space flight, especially in the initial stages of exposure to weightlessness.

This is in part due to the nature of the major space programs. First, the emphasis to date has largely been operational: addressing the physiological issues that might have detrimental effects on mission success. This is especially the case now in the US program: the majority of human research supports the development of future exploration-class missions beyond Earth orbit. Second, the population of space farers has been restricted (but for a few exceptions) to an elite group of specially selected and highly trained professional astronauts (cosmonauts, taikonauts). This population is not only extremely motivated and used to performing demanding tasks in high-stress environments,

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it is not representative of the general population in terms of fitness and health.

This landscape is about to change, with the advent of commercial space flights that will be available to most anyone who can afford the cost [1]. The first flights will be suborbital, leading eventually to orbital flights. Since the energy requirements and logistical complications are at least an order of magnitude greater for orbital flights, it is suborbital flight that will concern us here.

1.1. Suborbital flights

Several companies in the US and other countries are now developing the spacecraft and infrastructure for these suborbital flights, and the regulatory issues are being addressed by the relevant government agencies. Flight profiles vary but a typical trajectory will include 3–5 min of weightlessness (free-fall or 0g), bracketed by high-g ascent and descent phases. While these flight dynamics will be trying for some passengers, it is desirable for each operator to be able to fly the largest number of people possible in order to be profitable. Thus a wide range of passengers will be flying, with the required fitness level set as low as possible consistent with health and safety. This will be achieved through waivers and medical standards [2–4], but pre-flight training paradigms might also be helpful, especially centrifuge and parabolic-flight exposure (commercial providers exist who now provide these services [5]). It is worth noting that the experience base for human suborbital space flight is limited, consisting of two flights in the American Mercury program, one Soyuz abort, those few X-15 experimental aircraft flights that reached 100 km, and three flights of the SpaceShipOne commercial vehicle [6]. No major medical or human-performance issues were noted in these flights, although spatial orientation and control issues in one X-15 flight led to loss of vehicle and pilot (see below).

The large potential population of passengers and the variety of fitness and health levels are unprecedented in space flight. The chance to fly an experiment multiple times with minimal logistical complexity (relative to government-run space programs) opens new doors and provides a new set of opportunities for research in the life sciences. Herein are descriptions of some of these opportunities in general terms, delineated in four major categories of research, with a few examples of each. This report expands on a previous publication [7] that similarly discusses suborbital research potential; the current report provides more detail on specific possibilities, as well as advantages and disadvantages of the suborbital-flight platform.

2. Research categories

There are four main categories of human life-sciences research that might make use of suborbital flights. The critical characteristics of these flights will guide the research that can best make use of this unique setting:

- Brief but steady period of weightlessness, suitable to investigate systems with time constants too long for the 25 s of 0g in parabolic flight but short enough to be studied in a few minutes.
- Ready access to subjects, apparatus, and samples before and after flight.
- Ability to modify and repeat flight experiments in a reasonable time frame (days or weeks rather than years).
- Access to a potentially large and diverse population of test subjects.
- Possibility to acquire and archive life-sciences data on all subjects (passengers) who consent to a minimal level of physiological monitoring.

The final point is of special interest. A great deal of medical and life-sciences research data is currently archived by the major space programs. These data are available to researchers, but are protected for privacy and confidentiality. Access to the data is tightly controlled, in part because the release of some types of data might have a detrimental impact on a given person's perceived suitability for future flight assignments. Conversely, many commercial flight passengers have indicated a willingness to have their physiological responses to flight recorded and archived, and to participate as research subjects—they wish to be a part of the scientific process. (Indeed, one spaceflight tourist agreed to just such data sharing in relation to a trip to the International Space Station [8]). In order to take best advantage of this possibility, plans should be in place, when flights begin, to do the following (some of which are currently being pursued through the establishment by the US Federal Aviation Administration of their Center of Excellence for Commercial Space Transportation, http://www.coe-cst.org/):

- Establish a common set of biosensors for physiological measurement (EKG, respiration, etc.), across all flight operators [9].
- Encourage, or at least promote the opportunity for, passengers to consent to such measurements during their flights.
- Establish a common data archive for such data, and other life-science research data that might be acquired.
- Implement processes for widespread access to this data archive, by interested researchers with legitimate needs. Access should be made as broad as possible, so that exploratory research can take place rather than the more focused research that is typical for flight experiments. This is critically important, since interactions between physiological systems are insufficiently studied, and the extent of the changes that might take place on even short time scales is not fully understood so that exploratory research is needed as well as hypothesis-driven research. The ability to examine data across systems and studies, in a large population, would be a significant and unique contribution that could be made by the suborbital research community.

Balancing these advantages of suborbital flight are several disadvantages, relative to existing flight platforms:

- A source of research funds for these flights is uncertain. To the extent that the research coincides with the mission of one of the agencies concerned with the categories described below, that agency might be a source.

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