Opportunities for Research in Space Life Sciences Aboard Commercial Suborbital Flights

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The emergence of commercial suborbital spaceflight offers a wide range of new research and development opportunities for those in the space life sciences. Large numbers of diverse flyers, frequent re-flights, and flexible operations provide a fertile ground for both basic and applied science, as well as technology demonstrations. This commentary explores some of the unique features available to the space life science community and encourages engagement with commercial developers and operators during the design phase to help optimize platform designs and operations for future research.

Keywords: spaceflight, microgravity, commercial, tourism.

Since the 2004 launch of SpaceShipOne to win the Ansari X Prize, plans for commercial human spaceflight have blossomed, with more than $1.2 billion in new investments since that time (8). Prototype craft are already flying, with opportunities for unmanned suborbital payloads expected as early as 2010 and passengers as soon as 2011 (4). Recent market analysis by Futron Corporation projects that more than 13,000 space tourists may fly by 2021, suggesting a dramatic shift away from today's limited launch manifest of government-sponsored astronauts (5). Indeed, the space tourism industry is predicting peak operations of multiple flights per week. For the space life sciences community, these commercial flights offer a valuable new research tool. In Fall 2008, NASA launched a website focused on the Agency's suborbital research plans (6) and released a Request for Information on investigators' concepts.

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Research Environment

While designs and operations for suborbital craft vary widely, each flight will offer 2-5 min of milli- to micro-G access (6,10), a duration between that of parabolic aircraft (20-30 s per parabola) and unmanned sounding rockets (5-20 min per flight). Access to a suborbital window of microgravity may enable a variety of studies:

- Measurements of physiological responses to the transition to microgravity, including shifts in cardiovascular, cardiopulmonary, and sensorimotor variables, as well as human behavior and performance.
- Studies of fluid dynamics with time for acceleration transients to damp out.
- Microbiological investigations of changes in cytoskeletons, cell motility, and cell-cell interactions, with the added benefit of real-time observation and intervention (3).
- Testing and rehearsal of skills required for medical care in space, including airway management, diagnostic ultrasound, and emergency and invasive procedures.
- Production of novel mixed compounds of metallic or rapid-crystallization materials, as well as brief combustion research.

Because gravity is one of the fundamental forces of physics, it affects nearly all physical, biological, and chemical processes. An affordable, extended period of microgravity will allow broad application of the classic research paradigm, measuring an effect by removing it. As experimental materials and processes are exposed to the microgravity environment, new discoveries are inevitable. When suborbital craft carry the investigator, additional opportunities will certainly arise.

Because the new suborbital craft are designed to carry tourists, they must have relatively benign vibration and acceleration environments. Expected peak ascent loads will be on the order of 4-5 G ($>$ 2 G for $<$ 30 s), with peak reentry loads of 5-6 G ($>$ 2 G for about 30 s) (7), although some craft may exhibit transient loads of 10 G or more at parachute deployment or landing. The orientation of seated passengers with respect to these loads will vary by operator, but will likely be either $+G_x$ or $+G_z$. For some craft, reducing the flight apogee will allow operators to trade shorter exposures to microgravity for reduced peak accelerations, broadening both the passengers and hardware that could endure flights. Cabin atmospheric composition, pressure, and temperature are typically described as "shirtsleeve," though variations may be possible. The opportunity exists to use early test flights to characterize flight acceleration, temperature, pressure, and vibration, and to develop new research programs around standardized hardware interfaces and real-time payload sensing.

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Unique Enablers for Life Science Research

Novel highlights for the life science research community include changes in who flies and how flights will be conducted:

Large passenger populations will permit data collection on large numbers of subjects, raising the statistical power of biomedical studies and offering the potential for teasing apart differences based on age, sex, experience, and other factors previously obscured by small sample sizes and sample bias.

In contrast to the strict medical standards for professional astronauts, the Federal Aviation Administration (FAA) has published medical requirements that are performance-based and are expected to evolve with the industry (9): All crew with a safety-critical role must possess a Class II medical certificate and demonstrate ability to withstand the stresses of spaceflight, which may include high acceleration, microgravity, and vibration. Since then, a working group convened in 2009 by the Aerospace Medical Association has recommended that pilots of commercial suborbital flights undergo certification based on the FAA Class I medical certificate, including history and physical examination as well as urinalysis, hematological tests, and ECG (1).

The FAA does not require spaceflight participants to obtain a physical examination, but recommends such an examination in its guidelines (9). A 2009 study group of the International Academy of Astronautics prioritized such medical screening recommendations for short-duration (< 4 wk) commercial orbital spaceflight participants, aimed at identifying pre-existing conditions that could be aggravated or exacerbated by these flights (2). This report does not impose any formal requirements on the industry, but is intended to inform medical policy development by commercial spaceflight operators.

These flexible policies should allow access to flight for a diverse population that can be studied to shed light on interactions between microgravity and various disease states and medications. It also opens the possibility for researchers to fly with their own experiments. In this way, commercial spaceflight will be able to uniquely support procedures requiring high degrees of specialized training and to change the conduct of flight science by allowing real-time adjustments in settings or protocols. One can also envision studying flight crews and researchers who accumulate tens or even hundreds of flights in a career.

In addition to changing who flies, commercial suborbital spaceflight will also allow investigators to interact with payloads and passengers immediately before, during, and after flight, offering opportunities to observe fluid shifts, endocrine profiles, sensorimotor responses, and stress responses in real- or near-real time. Greater control over flight timelines can also be used to align missions with features of interest in pharmacokinetics, circadian rhythms, training schedules, and other time-sensitive research targets.

Suborbital operators will have greater flexibility for payload selection than is possible for orbital flights today, opening potential doors to payloads unable to fly on government vehicles. Hardware demonstrations can also advance the technology readiness levels of new systems. Accelerated timelines from proposal through flight will help researchers maximize the impact of their science. Experiments will be flown, analyzed, and quickly re-flown, and students may be able to take payloads from concept through operations in the span of a single academic year.

Maximizing Suborbital Opportunities

While suborbital craft are still in the design phase, now is the time for the research community to voice its needs for features that can enable future science investigations and technology demonstrations. Program managers and research institutions now have the opportunity to provide directed and effective funding of programs that will develop payloads to maximize these opportunities. Once this window for designing in cost-effective, strategic accommodations for payloads closes, developers and operators may lose the flexibility and cost incentives to responsively modify designs. Hence, it is incumbent upon interested customers to actively engage with the industry now.

Moving forward, an organized program for interacting with providers and flyers will help to maximize flight science. Helpful features will include standardized interfaces for flight hardware modules, clear requirements for human and animal experiment approvals, and incentive programs for engaging passengers in both active science and incidental data collection.

The emergence of commercial spaceflight will bring unprecedented opportunities for life sciences research. The number of potential subjects will grow rapidly and the ability to re-fly payloads will support targeted hypothesis testing and technology demonstrations. The reduced costs of flight hardware, frequent suborbital access, and significantly expanded time in low gravity offer an opportunity ripe for interrogation and innovation.

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