New Opportunities for Scientific Research Afforded by the Emerging Commercial Spaceflight Industry

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by
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Introduction

A new commercial human spaceflight industry is in the process of emerging. During the next decade, a range of commercial vehicles and facilities will become available. These vehicles and facilities can enable a range of scientific applications that have not been feasible or affordable in the past. Researchers and research organizations should take these vehicles and facilities into consideration when developing research plans, priorities, and roadmaps for the next decade.

Suborbital Vehicles

A number of private companies are working to develop fully reusable, suborbital space vehicles. These companies include Armadillo Aerospace[1], Blue Origin[2], Masten Space Systems[3], Rocketplane LLC[4], Scaled Composites[5], Virgin Galactic[6], and XCOR Aerospace[7].

These vehicles will be designed for aircraft-like operation. That does not necessarily imply horizontal take-off and landing, but it does imply aircraft-like characteristics including high reliability, short preparation and turn times, and the ability to safely recover from most in-flight failures. These characteristics are mandatory requirements for the low-cost operations and markets that suborbital companies are targeting.

Reusable suborbital vehicles will offer obvious cost advantages over expendable sounding rockets and orbit vehicles. Initial flights are expected to cost in the vicinity of $100,000-200,000 per seat (or seat equivalent), and these prices will decline over time. The low cost per flight and the fact that experimental equipment is recovered at the end of the flight will allow researchers to fly the same experiment repeatedly, rather than being forced to do one-off's.

The relatively low cost of suborbital flights will allow researchers to pre-qualify space hardware that is destined for more expensive orbital or planetary missions. Because the hardware is recovered at the end of the flight, it will be possible to qualify the actual unit that is destined to fly the operational mission, not just a "twin" unit. This can not only improve operational reliability but also eliminate the cost of building a twin for testing on an unmanned sounding rocket.

Similar testing is already being done on research aircraft flying microgravity parabolas. Such testing can and should continue, because microgravity aircraft provide even lower costs than suborbital vehicles. At the same time, microgravity aircraft cannot reproduce the full range of spaceflight conditions that suborbital vehicles can offer, including exo-atmospheric views, direct access to the space environment, radiation levels, and more flexible pointing abilities. While microgravity aircraft must fly a carefully defined parabola with the nose pointed into the wind, suborbital vehicles have fewer constraints once they are out of the atmosphere. The NASA Ames Research Center Suborbital Projects Office predicts vehicle pointing capabilities within ~ 1 degree.[8] Suborbital vehicles can also offer longer-duration microgravity and higher quality microgravity than aircraft offer. Dr. Alan Stern estimates that suborbital vehicles will offer 10 times the microgravity duration with 1/100 the disturbance level.[9]

Microgravity aircraft flights are actually a very good model for suborbital reusable vehicles. Suborbital vehicles offer many of the same advantages, including quick, easy access to experiments, specimens, and data recording devices before, after, and even during flight. The ability of researchers to accompany their experiments during flight will open up a new range of possibilities for experimental design. The short vehicle turn time between flights will allow multiple reflights of an experiment within days, or even hours. Scheduling flexibility will allow flights to be timed to coincide with short-lived phenomena, circadian rhythms, and research/class schedules.

Suborbital vehicles will also provide flexibility in flight location. Initially, suborbital flights will initially be restricted to small number of FAA-licensed spaceports, but as time goes on, the number of licensed suborbital spaceports in the US will increase. Former Shuttle commander and XCOR Aerospace chief test pilot Col. Rick Searfoss (USAF-ret) predicts that suborbital vehicles may cost about the same as a business jet, putting such vehicles within the range of many universities. For less than the cost of a new football stadium, a university could have its own space program.[10] Worldwide basing is also possible, if ITAR export considerations allow.

The research potential of commercial suborbital vehicles has already attracted the attention of NASA, which has established the Commercial ReUsable Suborbital Research (CRUSR) program. The CRUSR office has held two workshops to begin the process of gathering suborbital research ideas. The ideas received at these workshops include:[11,12]

- Earth science– direct atmospheric sampling at high altitudes on regular, responsive, frequent, and global basis.
- Helioscience – observation of solar storms.
- Biotechnology – documenting genomic precursors that initiate unique biology seen in microgravity.
- Atmospheric research – using chemical release and optical and mass spectroscopy to study the effect of chemical transport at the turbopause (95 km) on neutral and ionized species higher up in the lower thermosphere, dynamic instabilities and turbulent structures at altitudes where uniform atmospheric mixing breaks down, and the role of

atmospheric gravity waves in chemical and momentum transport.

- Investigation of Terrestrial Gamma-ray Flashes with frequent measurements, tailored on-demand launch windows, and altitude profiles not obtainable with balloons or sounding rockets.
- Planetary science investigations – study of dust aggregation and condensation with varying parameters to simulate the formation of planetesimals in the early solar system.
- Astrobiology –the potential survival of microbes and DNA at the edge of space.
- Materials science – the behavior of complex multiphase systems and multi-metal alloys in microgravity.
- Human physiology – in-situ monitoring of heart rate, cardiac stroke volume, arterial blood pressure, oxygen saturation, regional blood volume, EEG, and eye movements during both weightless and high-gee. Characterization of neurovestibular and sensorimotor responses, oculomotor control and perceptual disturbances, motion-sickness onset, fluid shift, and thoracic impedance. Evaluation of pre-screening methods and pharmaceutical countermeasures. Study of radiation on human physiology and pulmonary effects of lunar dust.

More recently, the Suborbital Applications Researchers Group was formed under the leadership of Dr. Alan Stern of the Southwest Research Institute.[13] The SARG also announced the first Next-Generation Suborbital Researchers Conference.[14]

These developments should be monitored and encouraged. NASA's CRUSR program can play a useful role in providing support and advise to researchers who have little or no previous experience in human-tended science experiments. Microgravity aircraft flights can provide useful near-term analogs for suborbital research programs. NASA might consider buying one or more microgravity flights for that purpose.

Teachers in Space

The development of reusable suborbital vehicles will create new opportunities for cost-sharing and cooperation. One example of such opportunities is the Teachers in Space, a non-profit program that seeks to put a thousand astronaut teachers into American classrooms within the next 10 years. TIS has already acquired 15 rides on suborbital spacecraft – 11 from XCOR Aerospace and four from other developers. These rides will be used to fly astronaut teachers, but TIS will also make space available to researchers who have secondary payloads and are willing to train teachers to operate the experiments in flight. In this way, Teachers in Space will serve double duty, benefitting both research and education.

Astrobiologist Lynn Harper of NASA Ames Research Center has described the possible benefits of this approach:

> Well-designed experimental controls are necessary for success in spaceflight investigations that are sensitive to many different environmental perturbations. This is especially true in the space laboratory sciences that include biology, materials sciences, physics, and technology testing and validation. Measurements that document the characteristics and changes from launch to landing in the dynamic flight environment for human suborbital flights are a necessary underpinning for designing sound science and engineering experiments by both professionals and students. Measurements of changes are essential for variables that include: gravity levels and directions, acceleration levels and directions, temperature, vibration, noise, gas composition, power fluctuations, oscillations and others over the flight interval. Experimental controls will be designed from such data, and decisions will be made on whether a suborbital platform is suitable for unambiguous results. This is foundational to good research.
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> However, baseline data collection is rarely funded because it is not the kind of ground-breaking research that is a priority in peer review. Worse, these measurements each require unique instruments that count against an investigator's resource allocations of weight, power, volume, crew time, and cost.
>
> Teachers in Space and their classes can provide an important service to researchers while providing a hands-on educational opportunity for their students in a real world situation by collecting these data on every flight and building a database that is put on the web for use in designing future investigations. Vehicle specific, flight specific, and trend data are important measurements that students can document and disseminate that would have professional caliber value.[15]

Orbital Vehicles and Facilities

Suborbital vehicles provide the greatest near-term potential for cost reductions and improvements in human-tended space science, but commercial space can also greatly enhance the effectiveness of long-term space research now being done on the International Space Station.

As the Space Shuttle program winds down, NASA is considering allowing commercial companies to carry crew to ISS. Initially, this will be done using space capsules and expendable rockets but in the long-term, these capsules might be replaced by safer, cheaper fully-reusable vehicles (descendents of the reusable suborbital vehicles now in development).

This poses a dilemma for ISS researchers. Lower-cost transportation would make ISS directly available to more scientists, but some experiments require long periods of undisturbed microgravity. NASA has mandated quiet periods and limited the number of ISS visits for this reason. One possible solution is to move these sensitive long-term experiments off ISS to a separate free-flyer derived from SpaceX's Dragonlab[16] or a Bigelow Aerospace module.[17]

Moving the more sensitive experiments off ISS to a separate free-flyer would open the door to expanding the station to larger numbers of researchers. Currently, the ISS crew is limited to 6 but the station has accommodated significantly greater numbers for short periods of time during Shuttle visits. With the addition of one or more inflatable modules from Bigelow Aerospace, the ISS crew size might be expanded to a dozen or more. With future vehicles that enable more frequent trips, an expanded ISS might serve hundreds of visitors each year, opening the door to educational and research possibilities we can barely imagine today.

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[1] www.armadilloaerospace.com

[2] www.blueorigin.com

[3] www.masten-space.com

[4] www.rocketplane.com

[5] www.scaled.com

[6] www.virgingalactic.com

[7] www.xcor.com

[8] NASA Ames Research Center Suborbital Projects Office, “Vehicle Capabilities.” http://suborbitalex.arc.nasa.gov/node/31

[9] Dr. Alan Stern and the Suborbital Applications Researchers Group, “Next-Generation Suborbital Spaceflight: A Research Bonanza at 100 Kilometers,” *Space News*. www.spacenews.com/commentaries/next-generation-suborbital-spaceflight-research-bonanza-100-kilometers.html

[10] Col. Rick Searfoss (USAF-ret.), personal communication.

[11] Col. Yvonne Cagle, MD. (USAF-ret.) “NASA’s Human Suborbital Flight Program.” http://suborbitalex.arc.nasa.gov/files/UpdatedSpaceAccessPresentation.ppt

[12] http://sites.google.com/site/commercialsuborbitalflight/

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[14] John Gedmark, “Next-Generation Suborbital Researchers Conference in February to Focus on Research & Education Uses of Commercial Suborbital Spacecraft.” http://www.commercialspaceflight.org/?p=689

[15] Lynn Harper, NASA Ames Research Center. Personal communication.

[16] Space Exploration Technologies Corp. “Dragonlab: Fast Track to Flight.” http://www.spacex.com/downloads/dragonlab-datasheet.pdf

[17] http://www.bigelowaerospace.com/