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Commercial Suborbital Spaceflight and Its Relevance to Responsive Space

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COMMERCIAL SUBORBITAL SPACEFLIGHT AND ITS RELEVANCE TO RESPONSIVE SPACE

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ABSTRACT

A major issue for responsive space operations is determining how to develop and operate launch systems that are both responsive and effective. This issue is also being tackled in parallel by the nascent commercial suborbital launch industry, as new vehicles are developed to support emerging markets, including space tourism. If these vehicles do come into high demand, they provide operational paradigms and other lessons learned that are applicable to responsive space operations.

The first section of this paper examines the markets that are being pursued by commercial suborbital vehicle developers. The best known, and largest, of these is space tourism, or public space travel. A market study performed by the Futron Corporation in 2002 shows that demand or such services will be high, at least by the standards of the space industry, with over 4,000 potential passengers per year by 2015 and over 15,000 by 2021. Meeting this demand will require hundreds of suborbital launches a year. In addition, other markets, ranging from remote sensing to microgravity science, have the potential to stimulate additional demand for suborbital launch services.

Suborbital flight's relevance to responsive space takes two forms. One, suborbital vehicles themselves can fill some of the roles envisioned for responsive space operations, such as reconnaissance and microsatellite launch. A bigger role, though, will be the operational lessons that suborbital spaceflight can offer to responsive space developers. Specific lessons will emerge over time, but will likely include the need for standard payloads and interfaces to shorten payload integration time, and the need for "aircraft-like" operations that require small teams and short periods of time.

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INTRODUCTION

The cornerstone of responsive space operations is the ability to launch payloads in a matter of days or even hours, as opposed to the timescales of months and years required today. Responsive space launch, coupled with advances in small satellite technology, could dramatically alter military space operations, permitting the launch of satellites in the event of a crisis to augment or partially replace existing space assets, as well as providing tactical services directly to the warfighter.

Implementing responsive space launch, though, requires breakthroughs not only in launch vehicle technology but also in launch operations. The months-long launch campaigns for a typical expendable launch vehicle (ELV) launch must be shortened to a few days, at most, to be truly responsive. One alternative is a "launch on demand" scenario, where launch vehicles are kept in "warm" storage, ready to be activated, mated with a payload, and launched within days. Such a system would be analogous to alert squadrons of aircraft and missiles, ready for flight on a moment's notice. Such a system would certainly be responsive (assuming it is technologically feasible), but carries the potential of significant costs to store and maintain vehicles that may not be used for months or years—if ever.

An alternative to the "launch on demand" scenario is an alternative "high demand" paradigm, where the flight rate is high enough that responsive operations become a necessity to keep up with the regular operational tempo. In such a scenario there is no need to stockpile launch vehicles specifically for responsive space operations, so long as military users have priority access to such vehicles when required. A disadvantage of this approach, though, is that it requires an overall launch market—civil, commercial, and military—that is large enough

to support high flight rates for one or more vehicles. Given the low levels of launch activity in recent years—the 54 orbital launches in 2004 were the lowest in any year since 1961—and flat demand for launch activity for the foreseeable future, this does not seem a likely development.

These issues present hard choices for the responsive space community as it grapples with how to implement responsive space. At the same time, though, a new commercial space industry is emerging: commercial suborbital spaceflight, using new vehicles designed to meet new markets, such as space tourism. This field may face some of the same challenges as responsive space in terms of launching vehicles with limited preparation time compared to conventional launch vehicles, and the approaches the suborbital industry takes to address those issues may be applicable to responsive space as well.

SUBORBITAL SPACEFLIGHT MARKETS

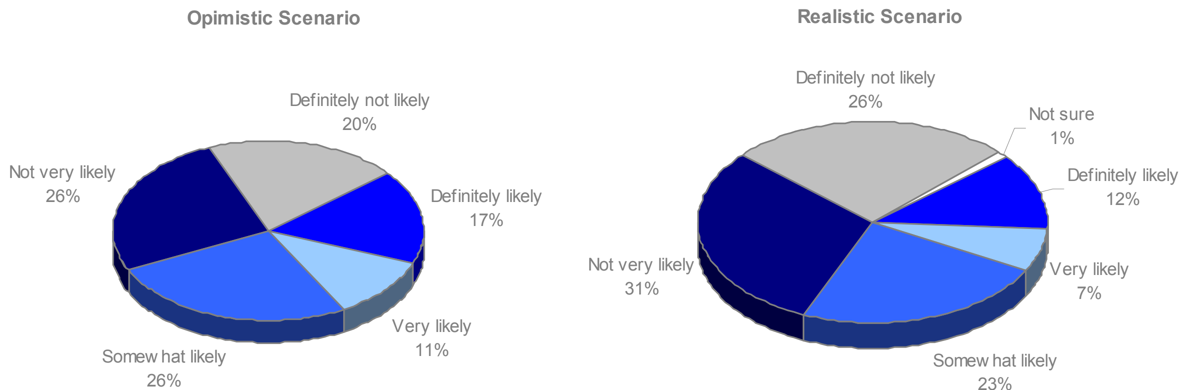
While suborbital spaceflight is hardly a new innovation, until recently it had been in the domain of military and civil government entities, who used suborbital launches for missile and missile defense tests, atmospheric sounding experiments, and astronomy observations at wavelengths of light absorbed by the atmosphere. There have been a handful of commercially-licensed sounding rocket launches since 1989, but these have been primarily for university or other non-commercial experiments.

However, the development of a new generation of piloted suborbital vehicles, built in part to compete in the $10-million Ansari X Prize competition, have promised to open new markets, most notably public space travel, more popularly known as space tourism. Over two dozen teams worldwide competed for the X Prize, which was won by Mojave Aerospace Ventures (MAV)—a team composed of Scaled Composites and financier Paul Allen—with two successful flights on September 29 and October 4, 2004. MAV and Scaled have signed agreements with Virgin Galactic, a subsidiary of Richard Branson's Virgin Group, to develop a follow-on suborbital vehicle to provide passenger services.

A number of teams that lost the X Prize are continuing their development efforts, including US-based entities AERA (formerly American Astronautics), Armadillo Aerospace, Rocketplane Ltd., and TGV Rockets. Several other companies that did not field X Prize teams are also developing commercial suborbital vehicles, notably Blue Origin, SpaceDev, and XCOR Aerospace. Their continue to be suborbital development efforts outside the United States by former X Prize teams and others, in locations ranging from Canada and the United Kingdom to Romania and Russia.

These ventures are pursing a number of commercial markets for suborbital spaceflight, the best-known and arguably largest of which is public space travel. In an effort to quantify the size of this market, the Futron Corporation embarked on a detailed market study in 2002 to gauge demand for suborbital and orbital passenger spaceflight. This *Space Tourism Market Study*, published in 2002 and freely released in 2004, incorporated survey data and economic analyses to provide the most quantitative projection of demand for commercial suborbital passenger spaceflight released to date.[1]

Figure 1: Interest in Suborbital Public Space Travel Based on Two Scenarios



The study is based on a survey of 450 individuals of high net worth conducted by the polling firm Zogby International for Futron. The respondent pool was limited to those people with annual incomes in excess of $250,000 or with net worths above $1 million, in order to gauge the interest among those people with the means to pay for commercial space travel. Those surveyed were asked about their interest level in suborbital and orbital space tourism and their willingness to pay at one of several selected price points; for suborbital spaceflight those price points ranged from $25,000 to $250,000 per passenger. Respondents were also asked to gauge their impressions of the risks of spaceflight versus other activities, such as mountain climbing and skydiving, their fitness levels, and their willingness to accept the training requirements for such flights.

The results showed a surprisingly strong interest in participating in commercial suborbital spaceflight, as shown in Figure 1. When presented with a basic, fairly optimistic description of a suborbital space tourism flight, with no discussion of cost, 54% indicated that they were somewhat, very, or definitely likely to participate in such a flight. When a more "realistic" description of the potential experience, with an emphasis on the risks inherent in spaceflight, that share dropped to 42%; the number who said they were "definitely likely" went from 17% in the first scenario to 12% in the second.

This survey was used as the starting point to construct a model of the demand for suborbital public space travel. Starting with the total population of affluent households worldwide, the model reduced the potential size of the market by eliminating those who were uninterested in such flights or unwilling to pay for those flights at specified price points, removing those who indicated a low level of fitness that would likely be incompatible with the stresses of spaceflight, and applying a "pioneering discount" to remove those people in the out years of the forecast whose primary motivation for undertaking such a flight would be to be among the first commercial space tourists. Selecting 2006 as the start date for suborbital spaceflight, the study applied a Fisher-Pry market diffusion model—a so-called "S"-curve—to phase in the market, reaching full maturity in 40 years.

The results are shown in Figure 2 below for the first ten years of the market forecast (2006–2015). The total demand for suborbital space tourism goes from just over 500 passengers in 2006 to 4,350 in 2015; by 2021 the demand reaches over 15,000 passengers annually. It should be emphasized that this study reflects the demand for suborbital spaceflight, and does not represent a prediction for the actual number of passengers who will fly in a given year, which will depend on the availability and flight rate of vehicles.

The study does allow, however, an estimate for the maximum number of suborbital flights in a given year, assuming an average number of passengers per flight. Figure 3 shows an estimate of that maximum, based on an average of five passengers per vehicle. That average is based on the estimated passenger complement of the SpaceShipOne follow-on vehicle under development for Virgin Galactic. The maximum number of flights goes from 100 in 2006 to 870 in 2015 and over 3,100 in 2021.

Figure 2: Demand for Suborbital Public Space Travel, 2006–2015, in Passengers

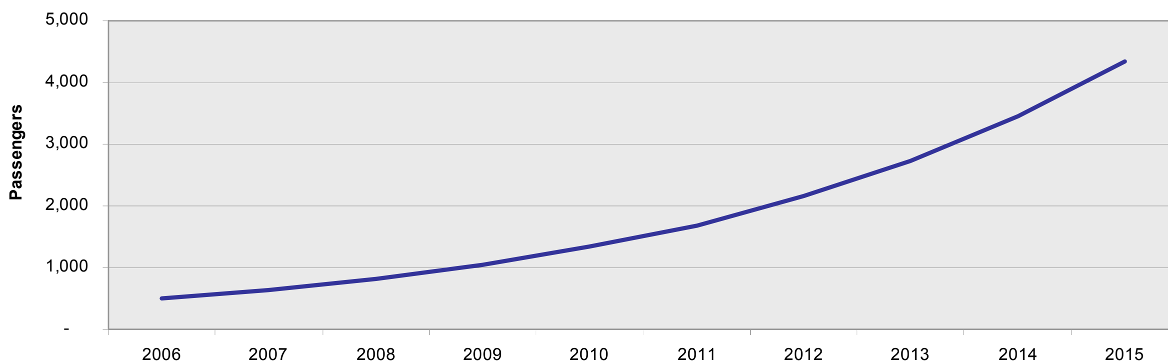
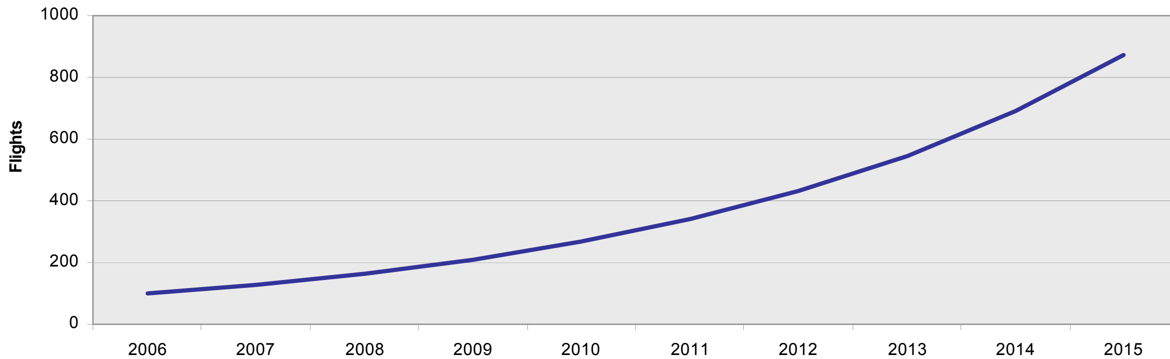


Figure 3: Demand for Suborbital Public Space Travel, 2006–2015, in Flights



While public space travel is the largest market for commercial suborbital spaceflight, it is not the only market being pursued or otherwise considered by vehicle developers. Alternative markets include astronomy and other high-altitude research; microgravity research; microsatellite orbital insertion; media, advertising, and sponsorship; space flight hardware qualification; and remote sensing and surveillance.[2] Unlike public space travel, though, the demand for suborbital flight services for these alternative markets has not been quantitatively determined yet, although some demand exists today that is satisfied through launches of expendable sounding rockets. In some cases this demand may not drive additional launches: flights of tourists, for example, could also incorporate an advertising or sponsorship customer, and experiments or other cargo could also be carried as secondary payloads on such flights on a space/mass-available basis.

RELEVANCE TO RESPONSIVE SPACE

The business of launching tourists into space for hire may seem far removed from developing a responsive space paradigm to meet the nation's defense needs. However, commercial suborbital spaceflight can provide both services and operational lessons that can improve responsive space activities in the future.

One role for suborbital spaceflight is to play a direct role in responsive space operations by carrying out missions to support, augment, or replace activities that would be carried out by responsive spacecraft or other space assets. One example is surveillance. A suborbital vehicle, launched on short notice, can quickly "pop up" to an altitude of 100 kilometers or above, providing theater-wide reconnaissance that can be instantly transmitted to forces in the area, including directly to the warfighter. In the case where battlefield communications were limited, the imagery could simply be stored on the vehicle and accessed a short time later, when the vehicle landed.[3]

Such a system could provide higher-resolution imagery than a comparable sensor in an orbiting spacecraft; additionally, since the spacecraft is not in an orbit that can be tracked and predicted, it can catch unaware opposing forces that might otherwise attempt to conceal themselves when orbiting spacecraft pass overhead. Also, since it can be based in a neighboring friendly territory, a suborbital system does not present the overflight issues associated with manned aircraft or UAVs. However, a suborbital vehicle would only be able to capture imagery for a few minutes during the peak of its trajectory, and thus would not have the long-duration surveillance capability that aircraft can provide.

Another role for suborbital vehicles is to serve as the first stage of a microsatellite launch system. In such a system the suborbital vehicle would deploy a satellite and upper stage—most likely, but not necessarily, expendable—near the peak of its trajectory; the upper stage would then provide the impulse needed to place the payload into orbit. This is analogous to the approach for DARPA's Responsive Access, Small Cargo, Affordable Launch (RASCAL) program that was recently terminated, although the aircraft lower stage did not reach the altitudes normally associated with suborbital spacecraft. One suborbital vehicle developer, XCOR Aerospace,

has been pursing the microsatellite launch market for its proposed Xerus suborbital vehicle. XCOR projects that it could launch satellites weighing up to 10 kilograms for $500,000.

While suborbital vehicles may play a role in responsive space missions, they can also provide a model for responsive space operations. As demonstrated in the previous section, demand for commercial suborbital passenger spaceflights will be high, and to meet even a modest fraction of this demand will require hundreds of launches a year. This can be accomplished by having a large number of vehicles that fly relatively infrequently (assuming that these vehicles are, in fact, reusable). However, a preferable approach may be to have a smaller number of vehicles that fly more frequently, amortizing the cost of each vehicle over a much larger number of flights, perhaps as frequently as once per week. Such a rate is not without precedent: the two X Prize-winning flights of SpaceShipOne took place five days apart, which included time to study a roll instability problem that occurred on the first flight.

The high flights and short turnaround times needed for such operations may provide lessons for responsive space, in particular for the "high demand" paradigm discussed in the introduction. While the actual nuts-and-bolts lessons learned will come only through actual flight experience, the requirements for a suborbital vehicle to carry out weekly (or similarly frequent) flights do suggest some general lessons that can be adopted by other responsive space systems.

One lesson is that payload integration time must be minimized, ideally through the use of standardized payloads. For commercial suborbital tourist flights, the payloads—individual passengers—are indeed relatively standard, at least compared to present-day satellites. Passengers will have similar dimensions and masses, making it straightforward to develop standardized "payload interfaces"—chairs and restraints—that are simple to use. A responsive space system can take a similar approach by working to develop a number of standardized satellites with similar characteristics that can be easily and quickly integrated onto a launch vehicle.

Another lesson is the need for "aircraft-like" operations. Such a phrase is often used in discussions of reusable launch vehicles without specific definitions, but broadly this term is usually intended to mean refurbishment and preparations of vehicles by relatively small teams (dozens rather than hundreds of people) in short periods of time (days or even hours). As noted above, this has already been demonstrated with SpaceShipOne during its X Prize flights in 2004. SpaceShipOne and several other proposed suborbital vehicles do, in fact, resemble high-performance aircraft than launch vehicles, including powered horizontal takeoffs and/or landings on runways, although other, vertically-launched proposed suborbital vehicles also plan aircraft-like turnarounds between flights.

CONCLUSION

One of the major challenges facing the responsive space community in the next several years will be developing responsive launch systems that effectively meet operational requirements. The "launch on demand" and "high demand" paradigms offer two different approaches to this problem, each with its own advantages and drawbacks. However, the responsive space community does not have to face these challenges alone: in parallel with their efforts, an emerging commercial suborbital industry will also have to develop ways to rapidly integrate and launch missions to meet the growing demand in the public space travel and other market sectors. Their efforts can provide key insights and lessons learned for responsive launch developers, and may also be able to fill some of the roles envisioned for responsive space operations in general.

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