IAC-12-B6-3.1 –x13280

A TRAINING FRAMEWORK FOR PRIVATE SPACE TRAVEL OPERATIONS

Derek Webber
Spaceport Associates, United States, DWspace@aol.com

This paper provides a basic structure to guide those preparing for the training of all associated parties offering space tourism services. This includes the crews of the space tourism craft, the passengers themselves, and those on the ground who are essential to the safe conduct of the flights. The paper, by bringing a pragmatic focus on the realities of the entrepreneurial space tourism business, substantially develops and extends the work of an industry team who worked within the aegis of the COMSTAC advisory council at the FAA-AST in the USA to help bring NASA experience to the assistance of the new space tourism sector. In particular the needs of the simpler sub-orbital space tourism experience are separated out from those of orbital operations, where NASA has previously gained the majority of its experience. Training is an essential part of the overall systems approach to providing safe operations, coordinated across the vehicle crews, passengers and their ground support team.

I. INTRODUCTION

It is very important for space tourism to be successful from the outset, at least in part because it is a key element in a paradigm shift that is taking place right now in the US in the realm of crewed spacecraft. NASA will rely on commercial taxi rides to get US astronauts into low earth orbit, and will concentrate their own development effort instead on getting beyond low earth orbit. For this plan to work, there needs to be a market for other passengers who wish to use these low earth orbit taxis in the seats not taken by NASA astronauts – and these will be the orbital space tourists and some experimenters. NASA will not now be providing the oversight that it did with all previous US spacecraft – from Mercury through Apollo to the Space Shuttle. In the US, NASA has been the repository for the accumulated fifty years of knowledge about crewed spaceflight, but now the responsibility for the oversight and regulation of the new commercial space sector, which will be providing the space taxis, rests with the Federal Aviation Authority (specifically FAA-AST). So, it is necessary to simultaneously capture all the knowledge related to safety and training that was hard-earned by NASA, while nevertheless tailoring it to the needs of the new entrepreneurial space tourism manufacturers and operators.

There is a very natural tension between the previous NASA approach, which worked well with a government agency employing many thousands of employees, and the contrasting needs of the new generation of manufacturers and operators who also require safety (arguably even more than the governmental vehicle support teams) but who do not have unbounded resources at their disposal. They need to be able to offer a safe and enjoyable service to their paying customers, and their very existence as a business depends upon it. So, there needs to be pragmatism in deciding how to proceed. In this paper, we first record some of the historical training methods that were employed in US, Russian and European training for space travel, and then examine how the FAA-AST in the US has attempted to capture NASA's knowledge about safety and training. Then, we address how best to work with this historical archive and produce a training framework suited to private space travel operations, whether for orbital or sub-orbital space tourism experiences.

Although it is perhaps tempting to at least suggest that experience as a glider pilot would probably be an advantage to any commercial pilots applying for commercial space tourism flight crew positions, we refrain from addressing the recruitment and selection process of aircrew or indeed any other staff of the operators or their ground support. This process will obviously be tailored by the operators in order that the new recruits bring with them substantial skills, education, certification and experience at the outset. Once on board, however, it is intended that they will be subject to the training regime being developed in this paper.

II. HISTORICAL TRAINING

There is ample record of the training regimes employed to date by those countries which have placed astronauts in space, especially with regard to the physiological training arrangements. Reference 1, for example, provides an overall summary. Reference 2 (written by one of the original Project Mercury

trainers) describes the US training regime, Reference 3 gives the Russian perspective and Reference 4 is a European source with rather less content. Reference 5 provides some information on the overall integrated training via simulation with ground support personnel.

With regard to the astronaut command crews, in the US, Russia and Europe the historical practice has been for around about a two-year training period for government astronauts. Included in this training, with slight variations between countries, has been:

-Fitness training
-Life support/suit training
-Flying skills
-High-g training
-Zero-g training
-Theory classes
-Survival training
-Emergency drills
-Simulator training/ground coordination

Various kinds of simulators were used, including attitude control, cockpit mission, docking and rendezvous system simulators.

Nine commercial space travellers have flown to date, starting with Toyohiro Akiyama in December 1990, and the last one being Guy Laliberte in September 2009. All of them flew in Soyuz, departing from Baikonur, which is now in Kazakhstan. The training regimes of these first orbital space tourists is summarised in Reference 1. They varied from 18 months to 6 months in duration (although market data quoted in Reference 1 indicates that most potential orbital space tourists would not want to spend more than one-three months for their training). Included in this training, again with slight variations between orbital tourism missions, has been:

-Fitness training
-Suit training
-High-g training
-Zero-g training
-Theory classes
-Survival training
-Emergency drills
-Housekeeping training
-Simulator training

And of course, up to now there has been no training regime specifically established for sub-orbital space tourists (although the first two US astronauts, Alan Shepard and Gus Grissom, flew sub-orbital missions and undertook the full training program of all the government astronauts, as described above).

III. THE FAA-AST CONTRIBUTION

Reference 6 addresses the overall position in the US/FAA-AST regarding training for private space travel (even including medical screening), and Reference 7 contains a fairly comprehensive list of commercial service providers who can each support part of the overall training requirement, once it has been formulated. It is, however, Reference 8 which is the real starting point for the analysis in this paper. It should be pointed out as a disclaimer that the present paper has not in any way been requested by the FAA, but is a private task undertaken by the author. The FAA's Office of Commercial Spaceflight (known as FAA-AST) has created a remarkable forum known as COMSTAC, which is an advisory committee of government, academic and industry experts to assist it as it brings this new private space travel industry into existence. COMSTAC has itself several working groups which evolve as the need arises, and in 2008 one such group began the process of assembling what emerged as Reference 8.

The Chairman of the task force which carried out this work (of which the author was a member) was Maurice Kennedy, who had been one of the original flight controllers (a Flight Dynamics Officer) during the Apollo program. During the Apollo missions, he was one of a team which included a Flight Director, Ops and Procedures, Launch Vehicle Systems, Spacecraft electrical, environmental and communications systems (EECOM), Flight Dynamics (FIDO), Guidance (GUIDO), Network control, Flight Surgeon (AEROMED), Retro/Re-entry/Recovery (RETRO) and others. He worked alongside such luminaries as Chris Kraft and Gene Kranz on the teams for Apollo 9, 10, 12 and 15. Obviously, he brought a very full knowledge base to the task on hand, and therefore the finished document (Reference 8) captures, perhaps just in time before the knowledge was lost forever, the key lessons of training gained at first-hand during the crucial initial years of human spaceflight. The document reflects the need for a systems approach to the training of personnel involved in space travel, emphasizing the need for group and teamwork. The approach made it possible to get men to the Moon and return them safely to Earth.

It is, however, too detailed for the needs of space tourism operators, and especially for those who are only planning to offer a sub-orbital space tourism experience. Therefore, this present paper is dedicated,

while saving the best bits of this NASA experience, to separating out the findings into orbital and sub-orbital elements, and then orienting them more pragmatically to the needs of space tourism operators (and less to a NASA lookalike organization). While doing this, we recognize that there will, in any case, be a wide variety of spacecraft designs and CONOPS associated with the new space tourism sector, and no single set of elements can be equally useful in each case.

The regulator (FAA-AST) has so far provided very little indication of what will be required in terms of training to satisfy the statute in providing space tourism services. In Reference 9, the regulator stated its minimum requirements. For flight crew, the training requirements are:

> -complete training…so that the vehicle will not harm the public
>
> -train in nominal and off-nominal conditions
>
> -withstand the stress of spaceflight
>
> -train for each mode of control or propulsion, including any transition between modes
>
> -train in procedures that direct the vehicle away from the public in the event the flight crew abandons the vehicle during flight; and
>
> -receive training for each stage of the flight, by using one or more of a) a simulator, b) a training aircraft having similar characteristics to the private space travel vehicle, c) flight testing

Regarding the passengers the regulator merely states:

> -an operator must train each spaceflight participant before flight on how to respond to emergency situations, with safety training to include emergency egress drills, fire, smoke, cabin pressure failure, etc.

There are various requirements of the operators to maintain training records and to ensure that pilot certifications are in order. And that's about it, so far as the formal regulations are concerned. So the Task Force preparing Reference 8 started with a clean sheet, and listed the anticipated space operations tasks for which training might be required for private space travel operations. Although originally these tasks were listed as *jobs*, traditionally carried out by different individuals in a NASA context, it was recognized that in the entrepreneurial space tourism context, one individual might carry out more than one of these tasks, so to reflect that realization, it is better in the space tourism context to view the following list as *functions*, rather than individual jobs. The list of functions potentially requiring training from Reference 8 is therefore:

- Pilot function
- Other Cockpit/Cabin Crew Function
- Flight Controller Function
- Planning/Ground Ops Function
- Spaceport Operator Function
- Maintenance Crew Function
- Passengers Function
- Space ATC Controller Function

There was some discussion of the idea of training standards, but in the Reference 8 document the idea was not developed beyond the statement that the phrase "training standard" used in the document was not meant in a regulatory way, but was intended merely to mean "that level of training needed to safely and effectively perform the required procedures associated with each function". Once the list of functions had been agreed, the task force members went on to produce a detailed 7-page menu intended to cover all anticipated private space travel operations. In fact, the list was so comprehensive that it even included such very NASA – specific functions as performing Extra-Vehicular Activities (EVA's).

Before we proceed to see how, from this work, the list of training emerges for both sub-orbital and orbital space tourism operations, we should note that already a series of commercially available facilities exist to be used as part of the physiological training process for private space travel. Reference 7 contains a listing of such offerings, which include high-g training, zero-g training, medical screening and pressure suit training. The NASTAR Center in the US provides centrifuge rides which can be designed to mimic the acceleration environment of any given space tourism operator (and Fig 1 shows their centrifuge).

Fig 1 Commercial high-g training centrifuge at NASTAR center

Both in the US and Europe it is now possible to arrange for zero-g flights within specially certified aircraft flying parabolic flight profiles, and Fig 2 is an image of the Novespace aircraft as it begins its parabolic profile which is giving a zero-g experience to those inside.

Fig 2. Zero-g experience is available via parabolic flight trajectory.

We should also note that there are some relevant new organizations who are working to promote safety in the commercial human spaceflight industry, including the Orbital Commerce Project, the Society of Aviation and Flight Educators (SAFE), and the National Aerospace Technical Education Center (Spacetec) (see, eg Reference 10).

IV. SUB-ORBITAL TOURISM TRAINING

In addition to Shepard and Grissom flying Mercury capsules in 1961, we can add Melvill and Binnie who both flew SpaceShipOne into space in 2004. And that's the total list of sub-orbital space travellers to date. So there is so far no generic list of procedures for training to conduct the upcoming sub-orbital space tourism flights. That is our task. We shall try to produce such a generic list of functions for which training will be required before the sub-orbital space tourism business can safely operate. And in this section, we identify this potential training framework.

There is no *a priori* assumption of a need for large numbers of people to do this work, even though Reference 11 quotes recent levels of 2,500 personnel at NASA's mission control supporting routine ISS operations. It may be possible to do all aspects of the work necessary for safety in a sub-orbital space tourism context with 5 or less people. However it certainly is intended that each and every item on the following list should be addressed in training, and therefore that each of the items will be included in the operator's training manual. The *degree* to which each of the items are covered, the *number* of people involved, and *who* shoulders the respective functional responsibility for the relevant piece of the operation, will however remain the responsibility of each operator to determine. It could well be the case that one person does the work (and receives the associated training) originally listed under job titles that in the NASA environment would have been carried out by, say, ten individuals. Clearly, however, it is important in each sub-orbital space tourism operator to make definite allocations of responsibilities for the functions and the people for whom this training is being proposed, with no piece being allowed to "fall between the cracks". We can now list as a training framework the series of functional tasks for which training should be provided. These tasks can be considered as section or chapter headings for a training manual for a sub-orbital space tourism operator, which will need to be sent to the FAA-AST as part of the regulatory oversight activities of that government agency before the commercial operation can begin:

Pilot related task training

-Fitness and Flying skills training
-Physiological training
-Vehicle familiarization training
-Spaceport/Control Center familiarization training
-Flight Plan familiarization training
-Nominal Operations training
-Contingency Operations training

Other Flight Crew Task training (where applicable)

-Same training as above, but variations in depth
-Passenger management and medical support training
-Experiment familiarization (where applicable)
(Note that the pilot will also need this training in operations where no other flight crew is involved)

Spaceport/Control Center function task training

-Flight control task training
-Planning/Ground Ops task training
-Spaceport Operator task training
-Space ATC controller task training

Maintenance Crew function task training

-Vehicle familiarization, including hardware and software training
-Detailed knowledge of facilities and special tool operations training
-Familiarization and practice with safety processes

Passenger/Experimenter task training

-Vehicle familiarization training
-Spaceport familiarization training
-Flight profile familiarization training
-Safety equipment and emergency procedures training
-Experiment familiarization and training (where applicable)
-Physiological training

We should perhaps point out that, although the passengers are tourists, they do carry some responsibility for safe operation and for obtaining maximum satisfaction for the relatively limited duration of the space experience, so they are aware that time must be devoted to this training. In the case of the orbital space tourists who have flown to date they even had to learn enough Russian so that they could handle the emergency procedures. Reference 1 records the initial proposed training regimes for the intending sub-orbital passengers, which vary from operator to operator, but generally take 3 to 5 days. The need for this training of the space flight participants is not only mandated by the regulator, but is seen by the operators as a positive part of the whole space tourism experience, and assists in marketing the operation as an astronaut experience.

V.ORBITAL TOURISM TRAINING

We now address the more complex operation, ie orbital space tourism. Although more difficult to safely perform, we know that orbital space tourism already exists and has been carried out satisfactorily by the Russians for decades. As described in the Historical Training section above, however, the Russian training took at least six months to carry out, and as Reference 1 points out, there is a need to try to constrain the orbital training schedule to less than 3 months and ideally to about 1 month, if possible for the future US-based operations. It will after all be of little use to develop such a comprehensive training program for the public spaceflight participants if a large segment of potential customers will be unable to take part because of the duration. The first handful of pioneer orbital space tourists did accept very long training periods, but it cannot be expected that this will be the case as the industry matures. For example, amongst the findings of the Futron/Zogby survey (Reference 12), the millionaire respondents indicated a 30% increase in likelihood to undertake an orbital space tourism flight if training time could be reduced from 6 months down to 1 month.

With that caveat about duration, the following list of headings can be seen as chapter or section headings in a training manual for an orbital space tourism operation, with various individuals having the responsibility to undergo a range of the training items. To underscore the need for team work and integration, some of these training tasks will be carried out by simulations with a number of different functions and people involved simultaneously. The training manual will be required to be reviewed by the regulator, FAA-AST, before the commercial operations can begin.

Pilot related task training

As listed for sub-orbital with the following specific detail elements:

-Vehicle Familiarization
- a. Instruments
- b. Life support
- c. Flight Management System
- d. Communications
- e. Electrical Power/Distribution
- f. Thermal control
- g. Propulsion and Attitude Control
- h. Abort system
- i. Landing system
- j. Safety tools

-Spaceport/Control Center familiarization
- a. Interface personnel policies and procedures
- b. Policy and regulations for flying into and out of airspace

-Flight plan familiarization
- a. Flight profile
- b. Mission plan

-Nominal Operations
- a. Spacesuit operations
- b. Pre-launch
- c. Launch
- d. On-orbit
- e. Crew and passenger health
- f. Rendezvous, Proxops, docking
- g. Undocking
- h. Re-entry
- i. Landing

-Contingency Operations
- a. Systems anomaly identification and response
- b. Trajectory anomaly identification and response
- c. Medical anomaly identification and response
- d. Survival training

Other Flight Crew task training

As listed for sub-orbital with the following additional requirement:

-Medical training

Spaceport/Control Center function task training

As listed for sub-orbital with the following specific detail elements:

-Flight Control tasks
- a. Flight director tasks
- b. Medical function
- c. Network ops
- d. Comms
- e. Experiment Familiarization (if applicable)

-Planning/Ground ops tasks
- a. Flight planning, cargo planning and integration
- b. Vehicle inspection and testing
- c. Pre-launch
- d. Post-landing

-Spaceport Operator tasks
- a. Console/workstation procedures for nominal ops
- b. Console/workstation procedures for contingency ops
- c. Safety processes for spaceport operations
- d. Incident and Accident response planning and Execution

-Space ATC controller tasks
- a. Console procedures including ATC interface for nominal ops
- b. Console procedures including ATC interface for contingency ops
- c. Familiarity with pilot and other crew responsibilities

Maintenance Crew function task training

As listed for sub-orbital

Passenger/Experimenter task training

As listed for sub-orbital with the following additional elements:

-Space suit training
-Air/Ground Communications
-Survival training

VI. CONCLUSIONS

This paper has reviewed the historical training regimes for spaceflight training, and has considered how this past experience, including the accumulated NASA experience of space operations, can be tailored to meet the needs of training for the new entrepreneurial space tourism businesses. A comprehensive training framework has been provided, which consists of the chapter headings for the operators' training manuals, for both sub-orbital and orbital space tourism operations. The aim has been to develop a training regime which will lead to safe operations, and allow for the team members – aircrew, passengers and ground support – to train together while at the same time allowing the individual operators to decide in practice how best to carry out this training. Ideally, if possible, the training for the space tourists themselves should be limited to 3-5 days for the sub-orbital experience, and not much more than a month for orbital space tourist candidates.

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