Flight Opportunities program

Analysis of the Quality of Parabolic Flight

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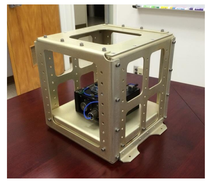
Abstract

Parabolic flights allow researchers to conduct several 20 second micro-gravity experiments in the course of a single day. However, the measurement can have large variations over the course of a single parabola, requiring the knowledge of the actual flight environment as a function of time. The NASA Flight Opportunities program (FO) reviewed the acceleration data of over 400 parabolic flights and investigated the quality of micro-gravity for scientific purposes. It was discovered that a parabolic flight can be segmented into multiple parts of different quality and duration, a fact to be aware of when planning an experiment.

Hardware and Data Analysis

The Suborbital Flight Environment Monitor (SFEM) is a compact, low power, self-contained user-programmable Commercial Off The Shelf (COTS) environmental sensor package used to measure values of acceleration level in reduced gravity flights. For this research, the SFEM was bolted to the floor of the aircraft in order to record the conditions encountered by researchers during zero-G flights.

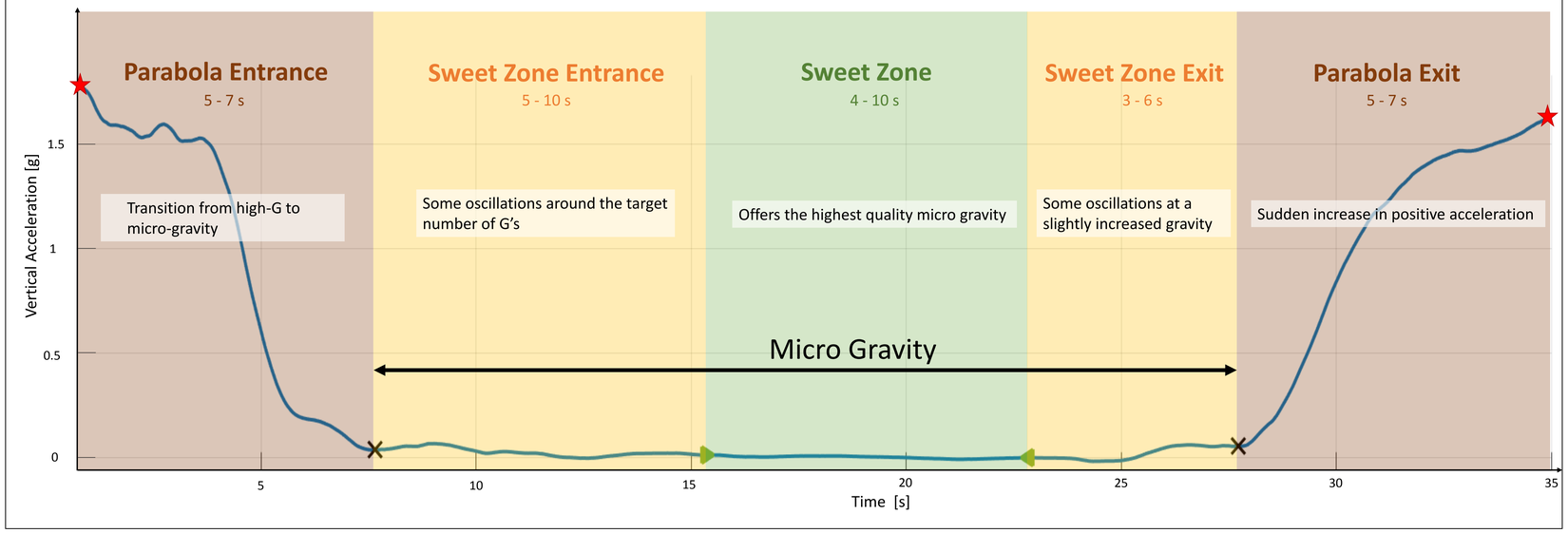


SFEM mounted in a payload rack

The data of the 3-axis accelerometer was filtered to eliminate the high frequency oscillations before integrating the signal twice in order to obtain an approximation of velocity and position versus time. An algorithm was specially conceived in Matlab to analyze raw data, automatically identify regions of interest for each parabolic flight and conduct statistical analysis.

Anatomy of a Parabola

A complete parabolic flight maneuver lasts around 60 s where usually 20 s are presented as micro gravity conditions. It is preceded and followed by a region of high-G (typically 1.6-1.8 G) corresponding to the aircraft pulling up to initiate or end the parabola. Data analysis showed that a typical parabola acceleration profile along the vertical axis can be divided into 5 zones as detailed below. On average, only 4 to 10 seconds of micro-gravity offer the optimal conditions for research, called the “sweet zone”.

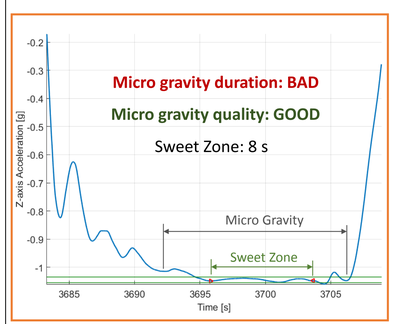


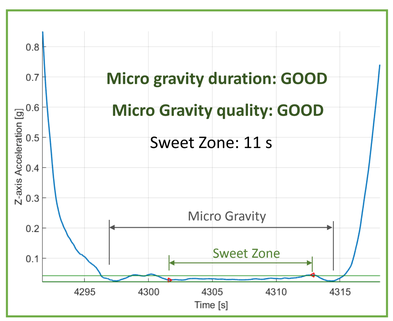
What is a Good Parabola?

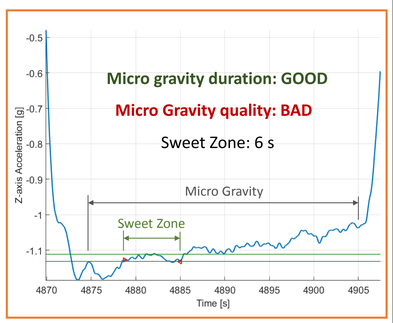
A “good” or “bad” parabola depends on the researcher’s experiment requirements. Some research requires a long duration in micro-gravity but is not sensible to small variations of acceleration while others need a shorter duration but very high quality zero-g with a limited amount of drift.

The answer will also depend on the configuration of the experiment. If the setup a “free-floater” type, small oscillations in the level of G will be of no concern but acceleration drift might cause contact with the cabin or other equipment. If the setup is bolted to the aircraft deck, small variations of acceleration could have an important impact on the obtained results.

Typically, parabolic flight providers advertise 10 to 20 seconds of micro-gravity with an accuracy of ± 0.01 to ± 0.05 G. Below are three examples of parabola acceleration. The red markers bound the Sweet Zone and the horizontal lines show the ± 0.01 G tolerance. The middle parabola gives an example of a “universally good” parabola while the two others can be either acceptable or not depending on the required application.



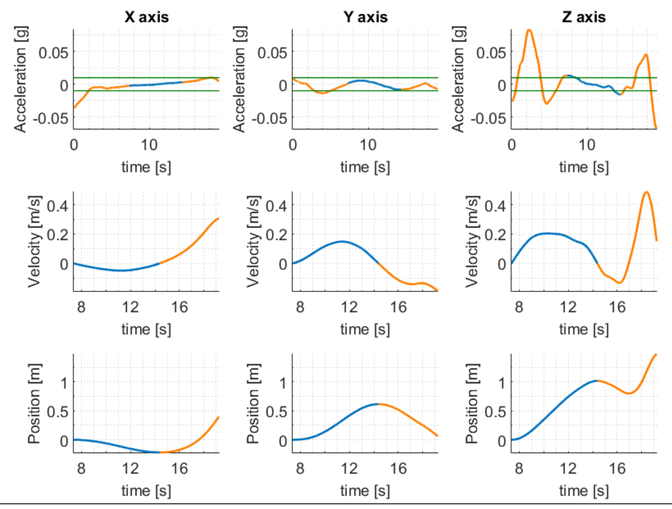




Movement During Micro-Gravity

Outside factors (aircraft, weather, pilot, etc.) can cause movement and therefore affect the quality of the micro-gravity section of a parabola. Most of this displacement happens along the vertical axis so the pitch of the aircraft has to be carefully adjusted to maintain the target number of G’s. From data collected, the average displacement within the Sweet Zone is of 1.3 m.

The plot below shows an example of acceleration, velocity and position versus time during micro-gravity. The blue part of the curve shows the Sweet Zone.



Parabola Quality Index

The Parabola Quality Index (PQI) is suggested as follows:

$$PQI = \frac{t}{\sigma} \times 1000$$

Where σ is the vertical acceleration standard deviation and t is time in micro-gravity.

A reference PQI_{ref} can be obtained based on the satisfactory standard deviation σ_{ref} for the experiment and its desired duration t_{ref}.

Parabolas with PQI > PQI_{ref} have acceptable data for that specific experiment.

Recommendations

When designing a micro-gravity experiment, researchers must be aware of the different regimes occurring during a parabola. The use of a 3-axis accelerometer is recommended to allow the research to determine whether the parabola quality is acceptable for the experiment.

A statistical analysis and more information regarding parabola quality will be available on the Flight Opportunities website soon.