SPACEFLIGHT

1505 Westlake Avenue North – Floor 6
Seattle, Washington 98109

September 10, 2021

FILED ELECTRONICALLY VIA IBFS
Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
45 L Street, N.E.
Washington, DC 20554

Re: Spaceflight, Inc.;
Errata to Application for Special Temporary Authority ("STA") to deploy and operate Sherpa-FX3, File No. SAT-STA-20210810-00097

Dear Ms. Dortch:

This letter responds to questions from the Commission regarding the above referenced application for special temporary authority for the Sherpa-FX3 spacecraft. Spaceflight hereby respectfully requests that Exhibit C of the above-reference STA request, be replaced with the attached revised Exhibit C.

Questions with respect to this matter should be referred to the undersigned.

Sincerely,

_/s/ *Will Lewis*___
Will Lewis
Sr. Manager, Regulatory

Exhibit C

Sherpa-FX3 Long-Term Recontact Probability

REVISION / DATE

A / 10 September 2021

Exhibit C

SPACEFLIGHT, INC.
1505 WESTLAKE AVENUE NORTH SUITE 600
SEATTLE, WASHINGTON 98109

REV	DATE	PREPARED BY	ANALYSIS BY	CHANGES
A	2021-09-10	W. Lewis	E. Lund	Initial Release

1. Introduction

The Sherpa-FX3 Mission (hereinafter “Mission”) on a SpaceX Rideshare launch, currently planned for January 2022, is a commercial rideshare mission with the primary Spaceflight, Inc. (“Spaceflight”) objective of hosting one customer payload which will remain attached to Sherpa-FX3, and deploying up to 8 customer spacecraft into a planned sun-synchronous circular orbit of 525 ± 25 km altitude. SpaceX’s Falcon 9 launch vehicle will deploy the free flyer vehicle, called Sherpa-FX3, which subsequently deploys the additional customer spacecraft within several hours of liftoff.[1]

The separation system and customer payload layout on the Sherpa vehicles can be variable, depending on the quantity of microsatellites and cubesats manifested to the mission. Cubesat and Microsatellite separation systems are interchangeable and can be affixed radially on the body of Sherpa. A microsatellite, cubesat dispenser, or other adapter for separation system mounting can be affixed on the outboard end of Sherpa. The Sherpa structure upon which the separation systems are affixed is identical to the previously licensed Sherpa-FX1, Sherpa-FX2, and Sherpa-LTE1. Thus, Sherpa-FX3 will deploy customers in the same fashion as the previously licensed Sherpas.

Currently, the planned configuration for Sherpa-FX3 has a microsatellite on the outboard end, with three (3) microsatellites, and a single 3U equivalent cubesat dispenser containing four (4) sub-3U cubesats attached radially on the body of Sherpa.[2] Sherpa-FX3 will also carry one approximately 5 kg hosted payload, subject to the provider of that payload, NearSpace Launch, securing its own separate authority for this mission from the Commission. The Sherpa-FX3 Mission configuration also includes an S-band receive antenna and an L-band transmitter as part of its avionics.

This report presents a probability of recontact for this mission based on the actual manifest and incorporates the worst possible change in manifest subsequent to filing.

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[1] Spaceflight notes that, as with any rideshare mission, there is a possibility that one or more customers will either not be ready, not be able to meet one or more of Spaceflight and/or SpaceX’s readiness criteria for flight or, choose to remove their spacecraft from the mission. Removed customers will be replaced by a non-separating mass model to keep the various launch and mission analyses valid. Since the Sherpa-FX3 does not have any attitude control, system dispersion is dependent on the momentum change after each deployment. This momentum change is based on the specific mass of each spacecraft and the spring energy in their separation system. Therefore, replacing a separating customer spacecraft with a non-separating mass model will change the momentum of the Sherpa FX3 and thus the deployment vector for subsequent spacecraft. In such event, a new recontact analysis will be run to verify the mission cumulative recontact probability. If the probability of recontact would be greater than that stated herein, a new sequence will be developed and tested to ensure that this threshold is met.

[2] None of the spacecraft to be deployed will themselves deploy additional spacecraft.

2. Methodology

Spaceflight has performed a high-fidelity analysis set forth below, using the same analytic techniques that Spaceflight described for its previously successful SSO-A and Sherpa-FX1, Sherpa-FX2, and Sherpa-LTE1 missions.

As a general matter, spacecraft with propulsion or differential drag capabilities should be able to avoid conjunction with another spacecraft. There are 3 spacecraft with propulsion on the mission. The propulsion systems on customer spacecraft identified in the STA filing are sufficient to enable them to perform collision avoidance. There are a number of variables, such as when customer spacecraft can activate propulsion, time to closest approach (TCA), or ground pass availability to command the spacecraft to perform a debris avoidance maneuver, that affect the ability of a given spacecraft to perform an avoidance maneuver. There is also some risk of conjunction in the period immediately following launch which is mitigated through the use of collision avoidance analysis between the launch vehicle and the Combined Space Operations Center (CSpOC). Additionally, the nature of that risk, and more generally of conjunctions involving spacecraft deployed as part of the Sherpa-FX3 Mission, is one better described as recontact rather than collision because of the low-speed nature of any possible conjunction. Contact at this low speed may cause minor damage to a spacecraft, but little or no debris.

The high-fidelity approach is based on a Monte Carlo analysis of a deployment sequence based on the current manifest. This analysis approach considers the mass and separation system properties for all Spaceflight customer spacecraft. Appropriate distributions are applied to these parameters based on customer and vendor inputs, and Monte Carlo simulations of the full Sherpa-FX3 Mission are run using a six degree-of-freedom orbit and attitude dynamics model with relative distances tracked between all spacecraft. Final mission analyses with our final configuration will show equal or better recontact analysis results and Spaceflight will provide those results to the Commission.

Sub-3U spacecraft will be grouped together in the same slot of their separation system and are therefore considered a single aggregate 3U spacecraft in these analyses. Sub-3U spacecraft are modeled as a single 3U spacecraft only when they are consolidated in a single dispenser slot (in the case of this mission, the 3U dispenser has 4 sub-3U spacecraft within). In this configuration, all of the spacecraft in the slot are deployed simultaneously and in the same direction and same initial velocity. These sub-3U spacecraft have very small springs between them to help push them apart gradually over time. The change in velocity caused by these small springs is substantially less than the spring energy variation margin that is included in in Spaceflight's Monte Carlo deployment simulation that applies for each dispenser slot. This means that the dispersal of the three sub-3U spacecraft will fall within the volume of space that is accounted for in that simulation therefore creating no greater recontact risk as so modeled than would be the case for single 3U spacecraft. These spacecraft would be deployed in the same velocity vector and thus relative velocities between them would be negligible compared to relative velocities between other spacecraft on the mission, or between Resident Space Objects. Ordering of the spacecraft within the dispenser will also help mitigate the chance of recontact, since they are intentionally designed with slightly different masses. By placing the least massive spacecraft with the highest separation velocity such that it is separated first, we thereby minimize the chance a spacecraft "catches up" to another spacecraft it was deployed with.

The probability of recontact is then found by counting the number of recontact events, which are said to occur if an object pair's relative distance falls below that particular object pair's combined hard-body radius and dividing by the total number of simulations run.

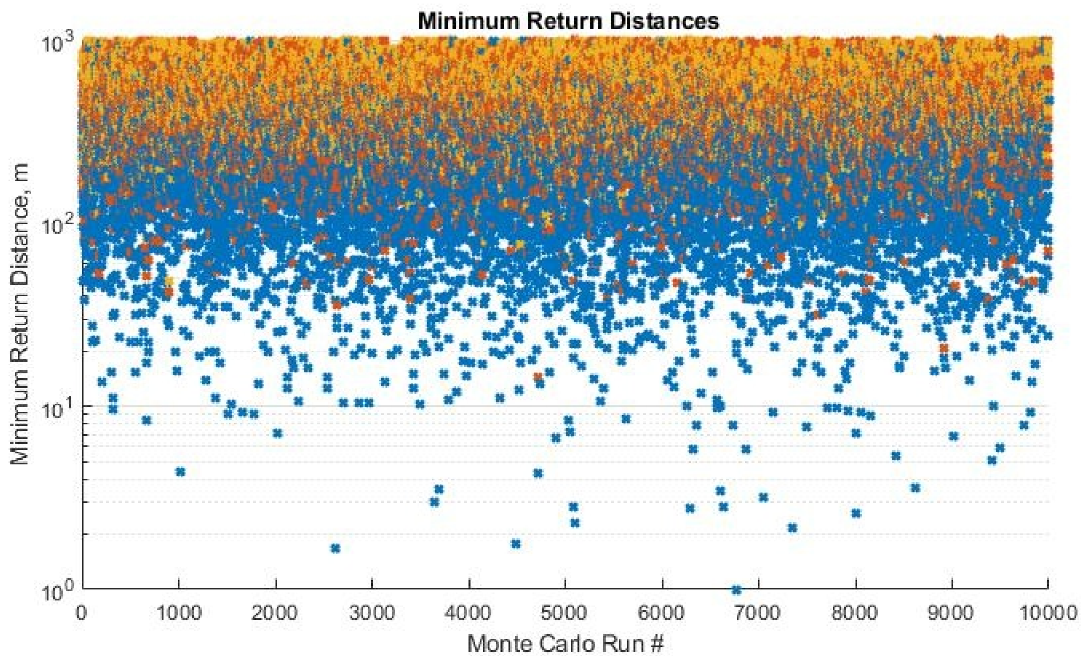

Figure 1: Results of 10,000 simulation Monte Carlo analysis over five orbits.

A 10,000-run Monte Carlo analysis was performed using this approach over a period that lasted five orbits after the last spacecraft is deployed from Sherpa-FX3 (a duration of approximately 8 hours) (Figure 1). The analysis was based on a deployment sequence that was chosen to reduce the probability of recontact. Further, this time period encompasses the period of highest spacecraft density where recontact events are most probable.

2000 further full deployment sequence simulations were run over a longer seven-day duration to substantiate this claim. In previous recontact analysis[3] we showed through binning of the relative miss distances, that the period immediately following separation through the first few orbits is the period of highest congestion, and the spacecraft diverge over time. With that in mind, we can conservatively assume this 2000 sequence, 7-day simulation's probability of recontact is fixed through two years, after the initial five orbit time period.

Any final modifications to deployment sequence order or timing from that which was used as inputs to the analysis here, shall have an equal or reduced probability of recontact than those presented herein. The five-orbit time period was chosen for detailed analysis because of the divergence of spacecraft that naturally occurs over this period, as further analyzed below. During this time (five orbits), two recontact event were observed (Pr(recontact) = 2×10^{-4}) with a $\Delta v < 1.0$ m/s.[4] There was a 99.0% probability that all

[3] SAT-STA-20200728-00089 Spaceflight, Inc. Sherpa-FX1 STA, Sherpa-FX1 Long Term Recontact Probability; SAT-STA-20210205-00017 Spaceflight, Inc. Sherpa-FX1 STA, Sherpa-FX1 Long Term Recontact Probability.
[4] Recontact was observed in 2 out of 10,000 simulations.

relative miss distances remained above 16.3 m, a 95% probability of all miss distances being greater than 43.4 m, and a 90.0% probability of all miss distances being greater than 66.8 m. When including the additional simulations, Spaceflight calculates that the probability for recontact between the spacecraft on the Sherpa-FX3 are, over a two-year period and even if none of the spacecraft to be deployed are capable of performing propulsive maneuvers, is 1.95 $x10^{-3}$. Considering the assumption that propulsive spacecraft will be able to perform debris avoidance maneuvers, the probability of recontact would be reduced to $9.74x10^{-4}$. During this time (five orbits) with propulsion maneuvers factored in, one recontact was observed (Pr(recontact) < $1x10^{-4}$) with a $\Delta v < 1.0$ m/s.[5]

2.1 Conjunction with Resident Space Objects

The analyses above addresses recontact between spacecraft on the Sherpa-FX3 Mission, which would be low velocity events. Another concern is the probability of a conjunction with a Resident Space Object (RSO) that is not part of the Sherpa-FX3 Mission. Each spacecraft is responsible for performing this analysis as part of their Orbit Debris Assessment Report (ODAR). Overall probability of conjunction with an RSO for all spacecraft can be estimated based on the individual spacecraft size and mass as an input into the Debris Assessment Software (DAS v3.1.0) RSO collision analysis. DAS predicts that Sherpa-FX3 and its deployed spacecraft, even if none of the spacecraft to be deployed are capable of performing propulsive maneuvers, have a probability of collision with RSOs of $3.69x10^{-5}$ over the entire orbit lifetime of the spacecraft. Assuming that the spacecraft to be deployed with propulsion systems would be able to avoid RSO collisions, given advance warning, including the FX2 vehicle itself, the probability of collision for non-propulsive objects with RSOs would be $2.57x10^{-5}$.

3. Conclusions

Spaceflight estimates that the combined probability of recontact for all objects on the Sherpa-FX2 mission is between $9.74x10^{-4}$ (assuming debris avoidance capability of propulsive spacecraft) and 1.95 $x10^{-3}$ (assuming none of those spacecraft have such capability), in each case using the approach described in Section 2. Adding the probability of deployed spacecraft and Sherpa-FX2 conjunction with a non-Sherpa-FX2 Resident Space Object provides a probability of recontact or conjunction with RSO of between $1.99x10^{-3}$ and $9.99x10^{-4}$, depending on whether propulsive spacecraft have debris avoidance capability.

[5] No recontact was observed in 10,000 simulations but the probability of recontact remains greater than 0.