SpaceX Fram2 Orbital Debris Mitigation (ODM) Worksheet - Revision 1

SpaceX voluntarily submits the following information regarding the Fram2 mission.[1]

1: Mission Overview	
1.1: Company Name	Space Exploration Technologies
1.2: Mission Name	Fram2
1.3: Mission Description	Falcon 9 will launch a Dragon commercial astronaut mission, Fram2, which will be the first human spaceflight mission to explore Earth from a polar orbit and fly over the Earth's polar regions for the first time. The mission is named in honor of the ship that helped explorers first reach Earth's Arctic and Antarctic regions. Mission aims are to highlight the crew's explorational spirit, bring a sense of wonder and curiosity to the larger public, and highlight how technology can help push the boundaries of exploration of Earth and through the mission's research. Throughout the 3-to-5-day mission, the crew plans to observe Earth's polar regions through Dragon's cupola at an altitude of 425 – 450 km, leveraging insight from space physicists and citizen scientists to study unusual light emissions resembling auroras. The crew will study green fragments and mauve ribbons of continuous emissions comparable to the phenomenon known as STEVE (Strong Thermal Emission Velocity Enhancement), which has been measured at an altitude of approximately 400 - 500 km above Earth's atmosphere. The crew will also work with SpaceX to conduct a variety of research to better understand the effects of spaceflight on the human body, which includes capturing the first human x-ray images in space, Just-in-Time training tools, and studying the effects of spaceflight on behavioral health, all of which will help in the development of tools needed to prepare humanity for future long-duration spaceflight. Falcon 9 will launch Fram2 to a polar orbit from Florida.

[1] The Commission's jurisdiction over space sustainability remains in question and untested in court. Nevertheless, in an abundance of caution SpaceX voluntarily submits this information to aid review of the pending STA request.

1.4: Number of Satellites	1
1.5: Launch Date	NET 03/01/2025
1.6: Launch Vehicle and Launch Site	Falcon 9, KSC LC-39A with LC-40 as an alternate.
1.7: Deployment Apogee (km)	210 km +/- 5 km
1.8: Deployment Perigee (km)	190 km +/- 2 km

1.9: Deployment Inclination (deg.)	90 +/- 0.02 deg.
1.10: Operational Apogee (km)	440 km+/- 5 km with variable phasing orbit up to 460 +/- 5 km
1.11: Operational Perigee (km)	420 km +/-5 km with variable phasing orbit down to 190 +/- 5 km
1.12: Operational Inclination (deg.)	90 +/- 0.02 deg.
1.13: Reason for Selecting Orbit	Polar exploration/research, phasing to landing sites
2: Spacecraft Information	
2.1: Provide a physical description of the spacecraft, including spacecraft bus, payload instrumentation, and all appendages, such as solar arrays, antennas, and instrument or attitude control booms.	The Dragon spacecraft is a fully autonomous spacecraft with both pressurized and unpressurized sections. Dragon is composed of three main elements: the pressurized section; the unpressurized service section; and the unpressurized "trunk" that provides the mating interface between the launch vehicle and the Dragon capsule. The pressurized section and unpressurized service section, as a whole, are referenced to as the "capsule." The capsule performs all the functions of a service module and is fully recoverable. Crew/Cargo accommodations and environmental control and life support system hardware are housed within the pressure section. The service section contains the propulsion system, main parachutes, avionics bay, and other miscellaneous components.

2.2: What is the effective Area-to-Mass ratio of the space station? Does the calculated Area-to-Mass depend on the successful deployment of appendages. If so, what is the Area-to-Mass ratio in a failed configuration. Does the Area-to-Mass ratio assume a tumbling orientation? [See NASA's Debris Assessment Software (DAS) User Guide for resources on computing Area-to-Mass Ratio]	SpaceX has assessed and limited the probability of becoming a source of debris by collisions with small debris, large debris or other operational space stations. An effective review and analysis of the failure modes associated with the Dragon spacecraft on orbit has been undertaken with insight from NASA. Additionally, SpaceX conducted internal reviews consistent with those done in coordination with NASA and all risks were deemed to be not credible, have been mitigated or controlled to acceptable levels.
2.3: Explain all systems related to satellite maneuverability, and whether or not the space station design includes a propulsion system.	Dragon's thrusters perform all on-orbit maneuvers, including operations such as rendezvous; deorbit bums; and attitude control throughout the mission, including during re-entry.

3: Launch and Deployment	
3.1: Prior to deployment, will the space station(s) be registered with the 18th Space Control Squadron or successor entity?	Yes
3.2: The extent to which the space station operator plans to share information regarding initial deployment, ephemeris, and/or planned maneuvers with the 18th Space Control Squadron or successor entity, other entities that engage in space situational awareness or space traffic management functions, and/or other operators.	SpaceX will share ephemeris with covariance to Space-track.org within hours of deployment and throughout the mission.
3.3: Provide a statement addressing the trackability of the space station(s). Will the space station tracking be active or passive?	Dragon is highly trackable and will be passively tracked by the Space Force Space Surveillance Network (SSN).
3.4: How does the operator plan to identify the space station(s) following deployment?	Since Dragon is highly trackable and the only object deployed on the launch, it will be easy to identify following deployment.
3.5: Provide a statement on the accuracy, if any, with which orbital parameters will be maintained, including apogee, perigee, inclination, and the right ascension of the ascending node(s).	Dragon's ephemeris accuracy has been validated internally by SpaceX and by NASA.
3.6: Indicate the anticipated evolution of the orbit of the proposed satellite or satellites over time.	Post deployment, Dragon will raise to a near circular orbit between 425 km and 450 km altitude. Once the mission is complete, Dragon will reduce altitude for

	reentry.
4: Satellite Operations and Collision Risk	
4.1: Collision with Large Objects	
4.1.1: What other space station or debris are present in the planned orbit(s)?	SpaceX will assume maneuver responsibility for any conjunctions with a collision probability above our threshold, unless event coordination requires a different course of action. SpaceX is using the same maneuver threshold as is used on crewed NASA Dragon missions.
4.1.2: Assess the potential risk of collision and provide a description of what measures the operator plans to take to avoid in orbit collisions.	SpaceX will execute conjunction risk mitigation maneuvers for any conjunctions with collision probability above our threshold.
4.1.3: If the space station operator is relying on coordination with another system, what steps will be taken to contact, and ascertain the likelihood of successful coordination of physical operations with the other system?	SpaceX will coordinate with any other systems if a conjunction event collision probability is above SpaceX's maneuver threshold. If contact information is not available on Space-Track.org, SpaceX will contact 18SDS to seek assistance in contacting the secondary object's owner/operator.

4.1.4: For geostationary space stations, a statement that assesses whether there are any known satellites located at, or reasonably expected to be located at, the requested orbital location, or assigned in the vicinity of that location, such that the station-keeping volumes of the respective satellites might overlap. If so, the statement must include a statement as to the identities of those parties and the measures that will be taken to prevent collisions. The statement should address any licensed FCC systems, or any systems applied for and under consideration. The statement need not address every filing with the International Telecommunication Union (ITU) that meets these criteria. The operator should, however, assess and address any systems reflected in ITU filings that are in operation or that it believes may be progressing toward launch, for example, by the appearance of the system on a launch vehicle manifest.	N/A

4.1.5: Assess the probability of collision between any space station of the system and other large objects (10 cm or larger in diameter) during the total orbital lifetime of the space station, including any de-orbit phases, to less than 0.001 (1 in 1,000). [Use the NASA Debris Assessment Software (DAS) or a higher fidelity assessment tool] If the operator will rely on collision avoidance procedures for reduction of risk, what is the threshold for a collision avoidance maneuver and the targeted risk reduction from any maneuvers undertaken?	For the Fram2 Mission, the collision probability between Dragon and other large objects (10 cm or larger in diameter) over the 3-5 day mission is well below 0.001 (1 in 1,000). SpaceX will mitigate any conjunctions with collision probability above the same threshold and to the same mitigation target as SpaceX uses for other NASA crewed missions. SpaceX's maneuver threshold and mitigation target for the mission are more conservative than those published in the NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook, i.e., 0.0001 (1 in 10,000) maneuver threshold and mitigation target of 5e-6 (factor of 1.5 below maneuver threshold).
4.1.6: If the mission includes a tether, assess the large object collision risk with the tether deployment, the impact on deorbit time, and a statement as to whether the tether can be retracted.	N/A
4.2: Collision with Small Objects	

4.2.1: Identify any critical surfaces, i.e. ones that if struck by small object debris or meteoroids, could cause loss of control and prevent post mission disposal. Assess the small object risk. [Use the NASA Debris Assessment Software (DAS) or a higher fidelity assessment tool]	SpaceX has engineered the mission to minimize the probability of collision from small debris and meteoroid strikes.
4.3: Proximity Operation:	
4.3.1: Will the satellite perform any close proximity maneuvers with other satellite or objects?	No
If the answer to 4.3.1 is yes	
4.3.1.a: Describe the planned proximity operations and address debris generation that may result from the proposed operations, including any planned release of debris, the risk of accidental explosions, the risk of accidental collision, and measures taken to mitigate those risks.	N/A
4.4: Debris Released and Deployment Devices	

4.4.1: Will any debris be intentionally released from the spacecraft?	SpaceX will not release any objects during normal Dragon on-orbit operations. Any object released during launch or reentry is analyzed for debris and collision avoidance and approved as part of the FAA licensing process.
If the answer to 4.4.1 is yes	
4.4.1.a: Prepare and provide a justification.	N/A
4.4.2: Will the spacecraft be deployed from a device separate from the launch vehicle (such as rings or other deployment vehicles, sometimes referred to as "free-flyers", but not including launch vehicles)?	No
If the answer to 4.4.2 is yes	
4.4.2.a: Provide a description of the deployment devices and a debris mitigation disclosure with respect to the deployment device. The debris mitigation disclosure should include a statement that the operator has assessed and limited the amount of debris released in a planned manner during normal operations, addressing facts such as the orbital lifetime of the deployment device and the collision risks associated with the device itself. If deploying multiple satellites, please include an evaluation of collision risk associated with the deployment of multiple satellites from the deployment device	N/A

4.5: Explosion Risk and End of Life Passivation	
4.5.1: What sources of accidental explosions before or after the completion of mission operations exist? Assess the probability of explosion occurrence.	In coordination with NASA, SpaceX has assessed and limited the probability of accidental explosions during and after completion of mission operations for NASA Dragon missions including a failure modes and effects analysis of the Dragon spacecraft. All risks were deemed to be not credible or have been mitigated or controlled to be within acceptable levels for NASA. For this mission, SpaceX has conducted internal reviews consistent with those done in coordination with NASA and all risks were deemed to be not credible or have been mitigated or controlled to acceptable levels.

4.5.2: What sources of energy (e.g. batteries, propellant, etc.) exist on-board the spacecraft? Could the conversion of such sources into energy (e.g. chemical, pressure, kinetic) generate debris that could fragment the spacecraft?	N/A as capsule reenters and is recovered.
4.5.3: How will the stored energy be removed at the spacecraft's end of life?	N/A
4.5.4: Are there liquids on-board the spacecraft that if released would persist in droplet form?	No
4.5.5: Are any of the on-board liquids ionic?	No
If the answer to 4.5.4 or 4.5.5 is yes	
4.5.5.a: **Will** these liquids evaporate or sublimate if released? How long would such liquid remain in orbit? Describe any natural processes that would result in dispersion of the droplets. How effectively is the ionic liquid contained?	N/A
5: Post Mission Disposal	
5.1: Will any disposal maneuver be performed?	Dragon missions utilize targeted reentry under license with the FAA, therefore, no "disposal" maneuver will be performed.

If the answer to 5.1 is yes	
5.1.a: How much fuel, if any, will be reserved for the disposal maneuver?	SpaceX reserves fuel for the reentry burn.
5.2: Which disposal method will be used?	Dragon is designed to safely execute a controlled reentry under license with the FAA into Earth's atmosphere after mission completion.

5.2.a.i: If passing <2,000 km, after end of mission, how long will the space station stay in orbit before atmospheric re-entry? Does the space station deorbit within 5 years after end of mission? End of mission is the time at which the individual spacecraft is no longer capable of conducting collision avoidance maneuvers. For spacecraft without collision avoidance capabilities, end of mission is defined as the point in which the individual spacecraft has completed its primary mission, e.g. communications services, handling customer message traffic, remote-sensing, etc. [Use NASA's Debris Assessment Software (DAS) or a higher fidelity assessment tool to compute orbital lifetime.]	N/A
5.2.a.ii: Assess whether portions of any individual spacecraft will survive atmospheric re-entry and impact the surface of the Earth with a kinetic energy in excess of 15 joules. Calculate the casualty risk for an individual spacecraft using the NASA Debris Assessment Software or a higher fidelity assessment tool and ensure that it is less than 0.0001 (1 in 10,000).	N/A
5.2.a.iii: If you are performing a controlled atmospheric re-entry (i.e. one targeting a specific geographic area) will the object re-enter substantially intact? If not, please address methods for mitigating on-ground risks. If so, re-entry may be subject to Federal Aviation Administration (FAA) licensing.	Dragon is designed to safely execute a controlled reentry under license with the FAA into Earth's atmosphere after mission completion.

5.2.b.i: What is the planned storage orbit and expected time to reach that orbit?	N/A
5.2.b.ii: For GEO satellites, what altitude is selected for a disposal orbit and what calculations (See 47 CFR § 25.283) are used in deriving the disposal altitude?	N/A
5.2.c: What is the plan for direct retrieval of the satellite?	N/A

5.3: If a post mission disposal (PMD) maneuver is required, will the probability of success of the chosen disposal method be 0.9 or greater for any individual space station? Elaborate on the computation of this probability. (For space station systems consisting of multiple space stations, the demonstration should include additional information regarding efforts to achieve a higher probability of success, with a goal, for large systems, of a probability of success for any individual space station of 0.99 or better)	Yes
5.4: If at any time during the space station(s)' mission or de-orbit phase the space station(s) will transit through the orbits used by any inhabitable spacecraft, including the ISS, what aspect of the system design and operational strategies, if any, will be used to minimize the risk of collision with, and avoid posing any operational constraints to, the inhabitable spacecraft?	SpaceX coordinates ISS avoidance directly with NASA.