Space Exploration Technologies

Dragon RF Information for the FCC – Fram2 (Initial Submission)

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1.0 REVISION/CHANGE RECORD

Date	Description
11/26/2024	Initial Submission

2.0 REFERENCES

2.1 Abbreviations

COTS	Commercial Orbital Transportation Services
CCtCap	Commercial Crew Transportation Capability
CTS	Commercial Transportation System
EIRP	Equivalent Isotropic Radiated Power
EM	Electromagnetic
EVA	Extravehicular Activity
GNC	Guidance, Navigation, and Control
ISS	International Space Station
kbps	kilo bits per second
ksps	kilo symbols per second
Mbps	Mega bits per second
Rx	Receiver
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
Tx	Transmitter

2.2 Applicable Documents

- SSP 50808 Revision F ISS to COTS Interface Requirements Document
- CCT-REQ-1130 Revision D ISS Crew Transportation and Services Requirements Document
    - CCT-REQ-1130 is only applicable to Crew

3.0 FRAM2 MISSION OVERVIEW

3.1 Public Background Information

No earlier than March 2025, SpaceX's Falcon 9 rocket will launch the Fram2 mission from Florida. Dragon and the Fram2 crew will spend up to five days in orbit, during which they will work towards the following objectives:

Fram2 will be the first polar-orbit human spaceflight mission to explore Earth. It will launch into a 90° circular orbit to the south from Florida, making it the first human spaceflight to fly over Earth's polar regions from low-Earth orbit.

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.

While in orbit, the crew will conduct scientific research designed to advance both human health on Earth and our understanding of human health during future long-duration spaceflights. This includes, but is not limited to:

- Capturing the first human x-ray images in space
- Just-in-Time training tools to the effects of spaceflight on behavioral health.

SpaceX will not be docking with the ISS as part of this mission.

Source: https://f2.com/ (Date: 11/22/2024)

3.2 Mission Type

As of the publishing of this document the following are the different Dragon 2 mission types as applicable to FCC license requests support documentation.

- Dragon 2 Crew ISS
  - Un-crewed vehicle references are not applicable to this mission type.
- Dragon 2 Cargo ISS
  - Crewed vehicle references are not applicable to this mission type.
- Dragon 2 Crew Freeflyer
  - ISS and C2V2 references are not applicable to this mission type.
  - Un-crewed vehicle references are not applicable to this mission type.

Fram2 Mission Type: Dragon 2 Crew Freeflyer

3.3 Mission Overview

3.3.1 Key Objectives

- Launch and return crew and capsule safely
- Perform science during the mission
- Mission duration ≤ 5 days

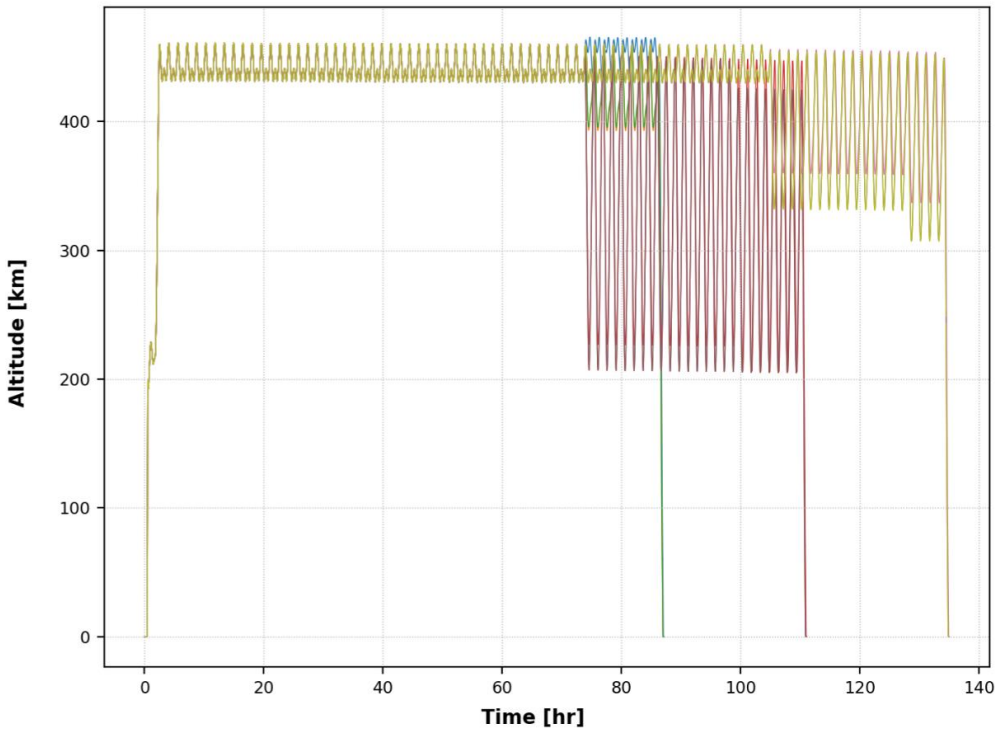

Figure 1: Mission Altitude Profile (Example Dispersions Shown)

3.3.2 Mission Trajectory

The Dragon 2 spacecraft's RF system is enabled throughout the launch of the Falcon 9 first and second stage.

The Falcon 9 first stage flight is suborbital. At approximately T+734 seconds the Dragon 2 spacecraft will be deployed from the Falcon 9 second stage. At T+1.2 hours, the spacecraft will maneuver to achieve a 430 km circular orbit at 90 degrees inclination.

Approximately 3 days after launch the Dragon 2 spacecraft will start phasing to its designated landing site by maneuvering to a variable altitude orbit between 190 and 460 km. Approximately up at a planned 86 hours after launch (up to 134 hours), the spacecraft will de-orbit and splash down.

3.3.3 Vehicle Configuration

- Capsule 207-4 (previously flown on Crew-1, Inspiration4, & Polaris Dawn)
- Nominal Sun+GEO pointing (similar to USCV) and Sun+Earth pointing (similar to Inspiration4)

3.3.4 TDRS Critical Periods

- Launch/Burns/Deorbit – same as USCV/Inspiration4
- Orbits with SAA passes

- All other times are considered non-critical, but for maximum crew safety we are requesting full scheduled wherever possible

3.3.5 Ground Antenna Locations

Fixed/Base Antennas:

- Inarajan, Guam , 13-16-56 North Latitude, 144-45-19 East Longitude
  - Antenna Gain: 37 dBi
  - Antenna Beamwidth: 2.38 degrees
  - Tx Power (W): 50W
  - Tx ERP (W): 5400
  - Tx EIRP (dBW): 40
  - Rx Figure of Merit (dB/K): 15.5
- Facility J6-1 Cape Canaveral, Florida , 28-37-27 North Latitude, 80-41-12 West Longitude
  - Antenna Gain: 35.4 dBi
  - Antenna Beamwidth: 1.9 degrees
  - Tx Power (W): 100W
  - Tx ERP (W): 5400
  - Tx EIRP (dBW): 40
  - Rx Figure of Merit (dB/K): 17.2
- SpaceX Launch and Landing Control Vandenberg AFB, California , 34-43-9 North Latitude, 120-31-52 West Longitude
  - Antenna Gain: 37 dBi
  - Antenna Beamwidth: 2.38 degrees
  - Tx Power (W): 50W
  - Tx ERP (W): 5400
  - Tx EIRP (dBW): 40
  - Rx Figure of Merit (dB/K): 15.5
- SpaceX Payload Processing Facility Cape Canaveral, Florida , 28-32-37 North Latitude, 80-35-25 West Longitude
  - Antenna Gain: 37 dBi
  - Antenna Beamwidth: 2.38 degrees
  - Tx Power (W): 50W
  - Tx ERP (W): 5400
  - Tx EIRP (dBW): 40
  - Rx Figure of Merit (dB/K): 15.5
- Kodiak, Alaska , 57-27-18 North Latitude, 152-22-25 West Longitude
  - Antenna Gain: 37 dBi
  - Antenna Beamwidth: 2.38 degrees
  - Tx Power (W): 50W
  - Tx ERP (W): 5400
  - Tx EIRP (dBW): 40
  - Rx Figure of Merit (dB/K): 15.5

Mobile Antennas:

- All share the same antenna specifications
    - Antenna Gain: 5 dBi
    - Antenna Beamwidth: 20 degrees
    - Tx Power (W): 1W
    - Tx ERP (W): 3
    - Tx EIRP (dBW): 7 dBW
    - Rx Figure of Merit (dB/K): -25.5
- Staged at any of several potential listed Dock and Recovery locations in the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean.
    - Pensacola Naval Air Station Dock - Ship Pensacola, Florida , 30-20-45 North Latitude, 87-16-1 West Longitude
    - Pensacola Recovery Location - Ship Pensacola, Florida , 29-48-0 North Latitude, 87- 30-0 West Longitude
    - Port Canaveral Dock - Ship Cape Canaveral, AFS, Florida , 28-24-47 North Latitude, 80-37-13 West Longitude
    - Port Canaveral Recovery Location - Ship Cape Canaveral, AFS, Florida , 28-51-0 North Latitude, 80-13-48 West Longitude
    - Jacksonville Recovery Location - Ship Jacksonville, Florida, 30-55-0 North Latitude, 80-15-0 West Longitude
    - Daytona Recovery Location – Ship Daytona, Florida, 29-48-00 North Latitude, 80-36-00 West Longitude
    - Panama City Recovery Location – Ship Panama City, Florida 29-42-58 North Latitude, 86-10-59 West Longitude
    - Tallahassee Recovery Location – Ship Tallahassee, Florida 29-16-59 North Latitude, 84-12-00 West Longitude
    - Tampa Recovery Location – Ship Tampa, Florida 28-06-00 North Latitude, 83-54-00 West Longitude
    - Port Tampa Bay Dock – Ship Tampa, Florida 27-55-46 North Latitude, 82-26-00 West Longitude
    - Tortuga Recovery Location – Ship Dry Tortuga, Key West Florida 25-08-06; 83-00-00 West Longitude
    - Los Angeles Recovery Location – Ship Los Angeles, California 33-40-43 North Latitude, 119-09-09 West Longitude
    - Oceanside Recovery Location – Ship Oceanside, California 33-00-43 North Latitude, 117-44-53 West Longitude
    - San Diego Recovery Location – Ship San Diego, California 32-36-10 North Latitude, 117-42-16 West Longitude
    - Dock – Port of Long Beach, California 33-44-38 North Latitude, 118-13-30 West Longitude

4.0 FRAM2 COMMUNICATIONS OVERVIEW

4.1 Applicable Requirements

The SpaceX dragon capsule adheres to the following NASA and US Government requirements (list not exclusive) for human rated spacecraft. These requirements dictate a minimum percentage of communication coverage between SpaceX mission control and the spacecraft. In order to meet these requirements, a wide geographic area is required; in addition to these requirements, multiple recovery location options are necessary for crew safety. These requirements are as follows:

Table 1: Requirements (CCT-STD-1140)

Section	Document	Requirement
7.1.11.1 (3)	CCT-STD-1140	For space-to-ground transmission, transmitter can only be on when a capable ground station is in view of the spacecraft and must be able to control power on/off.
7.1.11.1 (5)	CCT-STD-1140	RF performance standards are specified for the ideal condition; however, expected aggregate interference degradation based on an expected RF environment, structure blockage, vehicle orientation, antenna pointing direction, etc., should be factored into the final verification of 90% communications during ascent and 65% communications during reentry.
7.1.11.1 (8)	CCT-STD-1140	A minimum BER of 10E-08 measured at the output of a decoder with a 3dB margin should be maintained. This BER is not to be confused with the BER of the RF channel, which is typically much higher (10E-03, 10E-04).

Table 2: Requirements (CCT-REQ-1130 and SSP 50808)

ID	Document	Requirement Name	Requirement Text
R.CTS.351	CCT-REQ-1130 (Crew Only)	Command and Telemetry Communications	The CTS shall provide single failure tolerant command and telemetry communication between the integrated space vehicle and the CVCC(s) from pre-launch through landing and during aborts.
R.CTS.114	CCT-REQ-1130 (Crew Only)	Communications Coverage	The CTS shall provide communications coverage (two-way voice and telemetry) between the integrated space vehicle and CVCC(s) during at least 90% of the powered ascent flight phase and 65% during the entry flight phase to supported landing sites.
R.CTS.110	CCT-REQ-1130 (Crew Only)	Ground Monitoring and Operation	The CTS shall provide the capability for ground personnel to remotely monitor, operate, and control the integrated space vehicle and subsystems from the CVCC(s), where: a. The remote capability is necessary to execute the mission. b. The remote capability would prevent a catastrophic event. c. The remote capability would prevent an abort.

3.3.7.2.2.7	SSP 50808 (Crew Only)	SR-3.3.7.2.2.7 VEHICLE CREW ISSUED COMMANDS	B. The crewed COTS vehicle shall provide feedback to the vehicle crew and the vehicle control center that it has accepted safety critical commands sent by the vehicle crew.
3.3.7.2.2.2	SSP 50808 (Crew & Cargo)	SR-3.3.7.2.2.2 GROUND ISSUED COMMANDS	B. The COTS vehicle shall provide feedback to the vehicle control center that it has accepted safety critical commands sent by the vehicle control center. C. The COTS vehicle shall provide vehicle navigated state information and information to indicate any change of status of ground authorized go/no-go decision states to the vehicle control center.
3.3.7.1.2.1	SSP 50808 (Crew & Cargo)	SR-3.3.7.1.2.1 GUARANTEED COVERAGE WITHOUT PERTURBATIONS	For all nominal and planned contingency trajectories/attitude profiles (with the exception of breakout) the COTS system shall provide 100 percent continuous space-to-space communication capability within the ranges described in paragraph 3.3.7.1.1 and within the conditions defined in paragraph 3.3.3.2.18. This requirement is for communication capability, not antenna pattern or data quality; reference 3.3.7.1.2.5.

4.2 Dragon S-Band Communication System Overview

Figure 2 below illustrates the various radio frequency (RF) links that Dragon establishes during a mission.

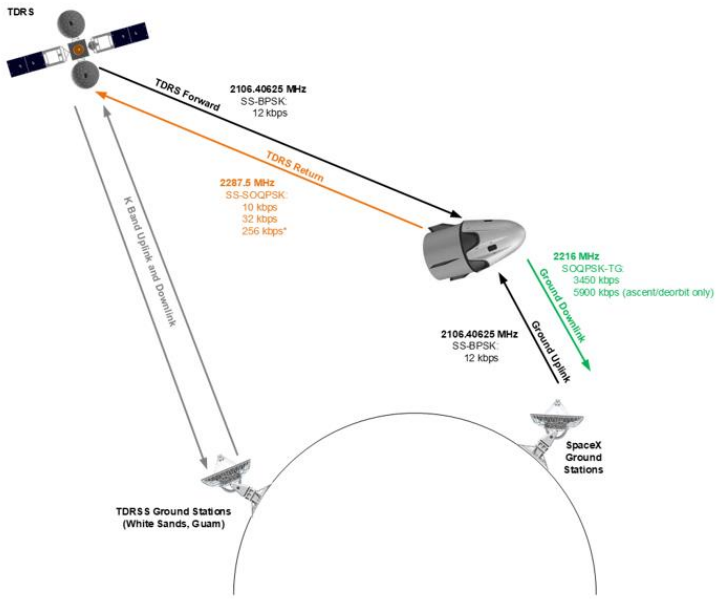

Figure 2: Fram2 S-Band Communications

4.3 Communication System Architecture

The Dragon 2 avionics system consists of three strings to provide redundancy. For the communications system, these strings contain equivalent hardware, with varied antenna positions. Each string has a transmitter that can switch between modes to maintain any single S-Band return link (TDRSS or ground). Each transmitter can select between 4 different antenna beams, making for a total of 12 possible antenna beam choices. Each of

the 3 strings of Dragon receive system uses 2 hybrid combined antennas to provide omni-directional coverage. Since there are 3 receive strings, there are 6 total receive antennas that constitute 3 hybrid combined antenna pairs.

4.4 Concept of Operations

Table 3 provides a typical mission timeline.

Table 3: General Mission Timeline

Mission Phase	Description
Ascent	F9 launch until Dragon separation from F9 Stage 2.
Far-field	Dragon separation and free flight
Deorbit	Starts with last deorbit burn, ends in splashdown.

4.5 TDRSS Return Link

For the Fram2 mission, the TDRSS Return link is always active. This link is spread spectrum, with a constant chip rate and variable bit rate. Modulation follows IRIG-106 SOQPSK-TG, except the B filter parameter is 0.9 instead of 1.25. TDRSS return link operates at 2287.5 MHz.

4.6 Ground Downlink

The ground downlink is only transmitting when there is a scheduled ground-station within line-of-sight. It is active from pre-launch to berth and from departure to splashdown. It is disabled for most on-station operations except for a few pre-departure checkouts.

Modulation is SOQPSK-TG, and the transmitter supports two data-rates, 3.45 Mbps and 5.90 Mbps. The -TG version of SOQPSK modulation follows the parameters noted in IRIG-106-22 Chapter 2, Table 2-4. The ground downlink operates at 2216 MHz.

4.7 Dragon Ham Radio Communication System Overview

Although the Fram2 mission is a private commercial flight on board or a Dragon capsule, one of the astronauts is a fully HAREC licensed amateur radio operator. Only the licensed astronaut will have full control of when the transmitter is enabled. The amateur radio experiments will be fully handled in accordance with amateur radio regulations and spirit and will not be used for any commercial, scientific, operational or other non-amateur use.

Table 4: Ham Radio Frequency and Operational Information

INPUT	VALUE
Frequency	Four frequencies in the 435-438 MHz band, currently being coordinated by

	the International Amateur Radio Union (IARU)
Output Power	10W
ERP	10.07W
Mean/Peak	Peak
Transmitter Frequency Tolerance (+/-)	0.005%
Bandwidth	16 Khz Maximum
Explain the Purpose of Operation	Experiment new radio amateur technologies from space and promote educational outreach. Possible candidates are Digital Voice and a SSTV "puzzle". Reference the "Fram2 Amateur Radio Notification" attachment
ITU Emission Designators	12K0F3E 6K25G1E 12K0F3F
Common description of emissions	NBFM DSTAR SSTV Robot 36
Operational Schedule	The transmitter will be enabled by the licensed astronaut periodically throughout the 3-5 day mission when there is antenna line of sight and link budget closure between the spacecraft and specific locations on the Earth.
Transmitting Equipment	Manufacturer Name: ICOM
	Model Number: IC-705
	Number of Units: 1
	Location: Dragon Spacecraft

4.8 Miscellaneous

4.8.1 Information Regarding the 2025-2110 MHz Band

Some requested frequencies may be within 2025-2110 MHz band, which is allocated to TV Auxiliary Broadcasting under Part 74F of the Commission's Rules. In order to avoid causing harmful interference to incumbent BAS licenses, SpaceX always coordinates operation in 2025-2110 MHz per FCC's requirement with the Society of Broadcast Engineers (SBE). Special conditions regarding coordination with the SBE can be found in previously submitted STA documents. It is SBE who makes sure that the use of this band is coordinated with broadcasters in the regions SpaceX operates such that there is no potential harmful interference.

4.8.2 Stop Buzzer Information in the Event that Interference Occurs

Phone 310-682-7125 or Internal Extension 7125

- Routes to the following call sequence:
    1. SYS1 Console: [310-363-6119]
    2. MD/CORE Console: [310-363-6122]