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NASA Centennial Challenges in Collaboration with Ames Research Center
Marshall Space Flight Center, Alabama 35812

Cube Quest Challenge
Ground Tournaments, Deep Space Derby Prizes, and Lunar Derby
Prizes

Communications Procedure for
Both In-Space Challenges
(CommsProc)

Rev. A: May 6, 2021

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DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline	1	December 18, 2014	Baseline
Revision	2	June 1, 2018	Updated references, expanded and refined procedures; simplified packet formats
Revision	3	March 1, 2019	Slight modification to key generation and seconds of time encoding
Revision	4	Oct 19, 2020	1. Added Table 4-1 – Team Identifiers 2. Added Table 5-1 – NASA Deliverables to Teams 3. Added Table 5-2 – Teams Deliverables to NASA 4. Added subsection in Section 4
		March 3, 2021	1. Section 3.0 – Definition. Capitalize the first letters of the term Competition Day and Operating Period. Added “Cube Quest Challenge Administrators” definition 2. Section 4.1, 1 st paragraph – append “within one day of their successful deployment from Artemis I SLS” to the second sentence to match the Rules 15 3. Added definition of PCAPNG, POSIX to Appendix A – Acronyms and Abbreviations 4. Section 4.3, Link Operation – Change wordings in 2 nd paragraph regarding radio operation regulation compliance 5. Revise section 4.4.2 to clarify the data generation algorithm 6. Update figure 4.1(a) and (b)
Revision	A	May 6, 2021	De-capitalize “Team Identifier” and “Operation Period Notice”

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1.0 INTRODUCTION

The Centennial Challenges Program (CCP) is the flagship program within the National Aeronautics and Space Administration (NASA) for technology prize competitions. The program directly engages the public, academia, and industry in open prize competitions to stimulate innovation in technologies that have benefit to NASA and the nation. See https://www.nasa.gov/directorates/spacetech/centennial_challenges/cubequest/index.html.

The CCP is an integral part of NASA's Space Technology Mission Directorate (STMD), which is innovating, developing, testing, and flying hardware for use in NASA's future missions. For more information about NASA's STMD, visit: <https://www.nasa.gov/directorates/spacetech/home/index.html>.

Beginning in 2015, NASA CCP began conducting the Cube Quest Challenge to take qualified small satellites, fitting the standard 6-U cubesat form factor, beyond low Earth orbit to demonstrate their operational techniques and technologies. That is, the spacecraft are not merely intended to survive, but to also demonstrate meaningful space operations in some manner. After a series of Ground Tournaments (GTs), qualified competitor teams were offered a secondary payload opportunity on NASA's first Exploration Mission (Artemis-1). These small satellites will be inserted into a trans-lunar trajectory for in-space Challenge purposes. Competitor teams may also select a third-party launch provider in order to participate in these Challenges. The Deep Space Derby Prize Challenge will be conducted once competitor team cubesats have achieved, and maintain, a range of at least 4 million kilometers from Earth. The Lunar Derby Prize Challenge will be conducted once competitor team cubesats have successfully achieved, and maintain, a verifiable lunar orbit as described in the *Cube Quest Challenge Operations and Rules*. Prizes will be awarded for various communications, navigation and longevity achievements that are performed under the conditions of the aforementioned *Rules*.

This document is a further explanation of the specific communications-related rules and issues found in *Cube Quest Challenge Operations and Rules* (OPSRUL). As such, all of the rules, constraints, and definitions found in the master document apply to this document. If any conflicts are found between this document and the OPSRUL, then the OPSRUL normally takes precedence unless the Cube Quest Challenge Administrators makes a waiver or notification in writing.

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2.0 APPLICABLE AND REFERENCE DOCUMENTS

The documents listed in this section are referenced in Section 4.0 of this document or are explicitly referenced in the *Cube Quest Challenge Operations and Rules*. While every effort has been made to ensure the completeness of these lists, document users are cautioned that they must meet all specified requirements of documents cited in Section 4.0 of this document, whether or not they are listed here.

Document revisions are current to the date of this publication. Unless specifically noted within the document, the most recent document revision shall be applicable. Document users are responsible to verify correct versions.

The NASA Centennial Challenges website will be the primary location for document(s) access and updates. Hardcopy versions will not be available, except for inhibiting circumstances.

2.1 Government Publications

Government specifications, standards, and handbooks in Table 2-1 form a part of this document to the extent specified herein. The government reference documents are listed in Table 2-2.

Table 2-1 -- Government Applicable Documents

Document #	Document name	Date	Revision
CCP-CQC-OPSRUL-001	Cube Quest Challenge Operations and Rules	See Revision Table: https://www.nasa.gov/cubequest/reference	
453-NENUG	Near Earth Network (NEN) Users' Guide	February 24, 2016	Revision 12
NavArt-03.06_NavArt	Required Navigation Artifacts	See Revision Table: https://www.nasa.gov/cubequest/reference	
NPR 2570.1	NASA Radio Frequency Electromagnetic Spectrum Management Manual	September 22, 2014	C
NPD 2570.5	NASA Electromagnetic Spectrum Management	July 11, 2011	E
Link	Spectrum Guidance for NASA Small Satellite Missions	August 27, 2015	Version 1

Table 2-2 -- Government Reference Documents

Document #	Document Name	Date	Revision
47 CFR 300.1	Manual of Regulations and Procedures for Federal Radio Frequency Management	May 2013	September 2015
FCC Public Notice DA: 13-445	FCC Public Notice DA: 13-445	March 15, 2013	
FCC Public Notice DA: 18-368	FCC Public Notice DA: 18-368	April 12, 2018	

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2.2 Non-Government Publications

The non-government specifications, standards, and handbooks in Table 2-3 form a part of this document to the extent specified herein.

Table 2-3 -- Non-Government Applicable Documents

Document #	Document Name	Date	Revision
JPL CL 17-2059	DSN Telecommunications Link Design Handbook	September 18, 2013	May 3, 2017

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3.0 CHALLENGE DEFINITIONS

The following definitions are related to the communications rules and are repeated from the *Cube Quest Challenge Operations and Rules* for reference in this document.

- "**Cube Quest Challenge Administrators**" is the challenge project manager and subject matter experts of the project team who organize the challenge.
- A "**data block**" is 1024 bits of random data generated by a NASA-provided algorithm as prescribed by NASA.
- "**Error free data**" and "volume of error free data" are determined by the number of unique (non-duplicative), whole data blocks delivered to the Judges that are free of transmission errors. Competitors may employ any error correction protocols (FEC, ARQ, hybrids) of their choice to achieve error-free data delivery.
- An "**Operating Period**" is a continuous 30-minute time segment during which the teams will officially attempt to receive data.
- A "**Competition Day**" is defined as a 24-hour period that starts at the respective time the Competitor Teams receives confirmation from their launch service provider of deployment from their respective CubeSat dispenser (regardless of whether deployed from SLS or from a Team-arranged launch vehicle). Each competitor will have their own start time at which their competition days begin counting.

As contained in Section 4.2.1 of OPSRUL, the "start of competition" notification will be provided by NASA for those satellites deployed on Artemis-1 (see Rule 15.B). For those satellites using a different launch vehicle, the Teams will need to notify the Cube Quest Challenge Administrators within 24 hours of their deployment event (see Rule 15.A).

NASA expects that operational passes will not necessarily align with Competition Days, i.e., the operational pass may start in one Competition Day and end in the subsequent Competition Day. Operating Periods are to align within a single Competition Day, i.e., an Operating Period may not span Competition Days. However, Operating Periods may be sequential so that as the first Competition Day ends with its Operating Period, a new Operating Period can begin at the start of the next Competition Day to maintain data flow. The notification for the Judges should be timed to show this scenario option.

As can be seen by these definitions, NASA does permit the teams to utilize some form of data protection against transmission errors. Teams may use some form of Forward Error Correcting (FEC) code or Automatic Repeat reQuest (ARQ) protocol to enhance their data transmission reliability. See the next section for more information on this option.

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4.0 RULES AMPLIFICATION

The following subsections contain the amplification of specific communications rules found in the *Cube Quest Challenge Operations and Rules*. Teams are referred to all the applicable government and non-government reference documents provided in Section 2. Special attention should be paid to the NASA NPR 2570.1C for how NASA approaches spectrum management and the governing documents for NASA projects from the National Telecommunications and Information Administration (NTIA), the Federal Communications Commission (FCC), and related standards. The “Spectrum Guidance for NASA Small Satellite Missions” document produced by NASA’s Space Communications and Navigation (SCaN) Program also provides important guidance for cubesat Radio Frequency (RF) spectrum use. Compliance with all federal regulations, such as 47 CFR 300.1, Manual of Regulations and Procedures for Federal Radio Frequency Management is required. For those teams contemplating using a NASA Near-Earth Network (NEN) ground station, the Near Earth Network User’s Guide contains useful information. For Teams contemplating using the Deep Space Network (DSN), the DSN Telecommunications Link Design Handbook contains useful information.

4.1 Mission Operations

Rules 15 through 25 cover the operations of the Challenge phases. Particular items to note are

- Rule 15 covers the start of the Competition Day for the Challenge. Note it is not based on a standard time but upon the deployment time. For Teams utilizing Artemis-1, NASA will inform the Teams of the deployment time within one day of their successful deployment from Artemis I SLS. For Teams using third-party launches, the Team must inform NASA of the deployment time. This can be done via an e-mail message. Also, see Section 4.4 below.
- Rule 16 covers ground stations. Teams are permitted to set their own operational schedules within each Competition Day. Teams are permitted to communicate with their spacecraft outside of the Challenge data transfer times. However, because the Teams will be operating in close proximity and they need to avoid interference, Teams will need to coordinate their transmission activities so that spectral interference does not occur.
- Rule 17 covers the mandatory planetary protection requirements. Teams are required to adhere to their approved operational plans for planetary protection. Improper adherence may result in the forfeiture of prizes.
- Rule 18 covers the rules for the data packaging and delivery to NASA. More detailed information is provided in Section 4.4 below.
- Rule 19 covers the defining method for the end of the Challenge.
- Rule 20 states that the CCP is not responsible for any potential loss of prizes if there is a deployment malfunction.

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- Rules 22 through 24 cover the prizes for the different competitions. Teams must note that the prizes are subject to verifying orbits based on the specifications in “Required Navigation Artifacts.”

4.2 Radio Frequency Licensing

Rule 5 of the OPSRUL and subsequent Rules require each team to properly submit and maintain any necessary RF licensing for their spacecraft and, if necessary, for their ground station. **Note:** NASA will not manage the submission of the licensing request for either the spacecraft or any non-NASA ground facility.

It is a Team design decision to choose the appropriate use frequency and license, e.g., an experimental license at S-Band. The Teams must coordinate these details with the appropriate licensing authority. **Note:** the FCC, in Public Notice DA 18-368, has specified that licenses must be issued before spacecraft launch. Compliance with this Notice is mandatory. Therefore, Teams must submit proof of RF license authorization to the Cube Quest Challenge Administrators before beginning operations in space. This includes both the cubesat authorization and any ground station authorization. This is required at least 30 days prior to launch or by the date specified by the launch provider, whichever is earlier.

4.3 Link Operations

Each Team is expected to operate their spacecraft and ground stations in accordance with their license terms and in accordance with good engineering practice. It is the responsibility of the Teams to ensure that all transmissions are conducted to comply with their license grant and maintain sufficient link quality to ensure correct reception of telecommand and telemetry data. NASA is not responsible for any loss of prizes due to poor signal quality that affects spacecraft or ground station operations.

Because there may be multiple teams operating in a common area, it is the responsibility of the teams to coordinate transmissions so that interference does not affect link quality. Teams shall comply with FCC regulations.

Teams operating in the same general region, e.g. Lunar orbit, must develop an operational RF coordination plan and submit it to the Cube Quest management office and have the plan approved by NASA at least 30 days prior to launch.

4.4 Data Transmission Methodology

This section describes the method of data transmission for competition prize and format of the data packet.

4.4.1 Operating Periods Plan

Rule 15.B specifies that each Team shall begin their Competition Day based on their separation time. To allow NASA to plan for understanding when the Team may be attempting transmissions to meet the Challenge, *Rule 18.A* requires that each Team shall inform Judges of the Challenge

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Operating Periods the Team plans to utilize for the next 24 hours, beginning at the start of the next Competition Day. Operating Periods shall not span Competition Days. This notification shall be submitted at least 24 hours before the start of the Competition Day. **Note:** Operational passes that span multiple Competition Days shall have unique notifications for each Competition Day and the Operating Periods within those days. The notification is to be sent in American Standard Code for Information Interchange (ASCII) text format, with read receipt enabled, to the specified e-mail address that the Cube Quest Challenge Administrators will provide to each Team. Teams may operate more than once per Competition Day, depending upon the schedule the Team negotiates with the ground station owner. The notification shall contain, at a minimum,

- The Team Name, the team identifier,
- A point of contact for the Operating Period and contact information (e-mail, and telephone at a minimum),
- The UTC date and time for each anticipated Operating Period in the 24-hour Competition Day.

The UTC time for Each Operating Period in the notification message must be the same time and in the same format as the time used in generating the random data for that Operating Period as described below in *Rule 18.B*.

If the Team does not announce Operating Periods, then Judges shall not consider any operations that day for competition purposes.

4.4.2 Data Packets Format and Random Data Generation Algorithm

Rule 18.B specifies that Teams shall generate their random data using the algorithms and protocols specified in this document. Judges shall not accept data generated by any other methodology. The data generation methodology shall be

1. NASA assigns the Team with a unique team identifier that is 32 bits in length. The Team will use this key in generating the random data and include the key in the transmission containing Challenge random data. Table 4-1 shows the list of Team Identifiers from which one will be assigned to each participating Team. Figure 4-1(a) shows the placement of the Team Identifier with the random data in forming the individual data.
2. Data packets are defined as 1152-bit units (144 octets). Multiple data packets can be generated consecutively; however, each data packet must be packaged individually with a 16-byte header as illustrated in Figure 4-1(a). The packet includes the following fields:
 - a. The 32-bit (4-byte) unique team identifier to act as the synchronization code for the data block.
 - b. The 32-bit (4-byte) data block sequence number as a hexadecimal integer; this counter increments sequentially from the start of the Team's first Challenge data transmission.

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- c. The time stamp for the start of the Operating Period in this particular 24-hour Competition Day formatted as a 32-bit POSIX number of seconds since 1 January 1970 and a 32-bit microseconds of seconds field (pad with random 1s and 0s if necessary to fill this field). If the microseconds data are not generated by the flight computer, use the hex constant AAAA for this field. Each Operating Period shall have a unique time stamp and the team may not use it to generate data beyond the end of the Operating Period.
 - d. The unique 1024-bit (128-byte) random data block.
3. Teams are free to design their best method for encapsulating the data packet for transmission over the channel to the Earth station. The Challenge requires that, upon reception, the individual data packets are then concatenated into a single stream as Figure 4-1(b) illustrates for verification. The maximum number of data packets in a single transmission wrapper protocol is left for the Team to determine based on data protocol format constraints, coding methodology, and operational constraints. Only complete data packets will be counted in Challenge scoring. See *Rule 18.D* below as well.
4. The random data shall be generated from a Pseudo Random Number (PRN) linear congruent generator using the algorithm

$$x_{n+1} = (ax_n + b) \text{ mod } M$$

where x_0 is the seed value computed from the team identifier, the Operating Period start time, and the block sequence number in the header. The values for a , b , and M shall be

- a. $1664525 \equiv a$
- b. $1013904223 \equiv b$
- c. $2^{32} \equiv M$

Modulus M is equivalent to keeping each x_n value to 32 bits.

The initial seed, x_0 , is computed using the information from the Data Packet Header. The Operating Period base seed value shall be computed by bitwise XORing the 32-bit team identifier and the 32-bit Operating Period seconds value of the time stamp to produce the base 32-bit seed value. For each 128-byte PRN data block within the Operating Period, the seed value for the block shall be the computed by XORing the 32-bit Operating Period base seed with the 32-bit PRN Sequence Number for the block. Each new PRN block will need a unique seed for that block. The PRN includes x_1 through x_{32} , with each x_n , as a 32-bit unsigned integer.

Operating Period Seed = (Team ID) \oplus (Time[seconds])

Seed of Block x_0 = (Operating Period Seed) \oplus (Sequence Number)

where \oplus = bitwise XOR

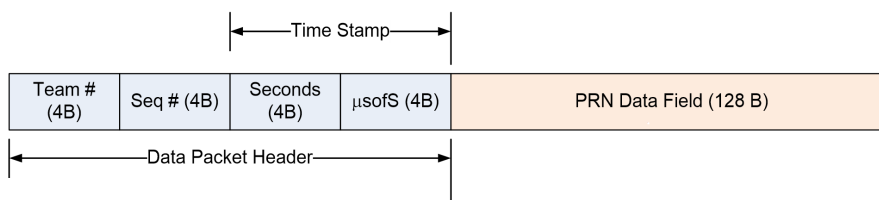
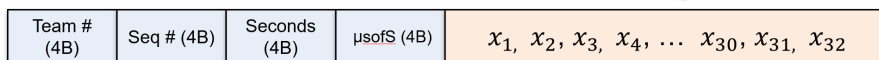
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Table 4-1 -- CubeQuest Team Identifier Numbers (hex format)

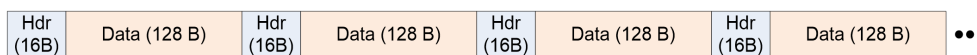
Team	Identifier (0x)
1	EB901E1E
2	EB902D2D
3	EB903C3C
4	EB904B4B
5	EB905A5A
6	EB906969
7	EB907878
8	EB908787
9	EB909696
10	EB90A5A5
11	EB90B4B4
12	EB90C3C3
13	EB90D2D2
14	EB90E1E1
15	EB90F0F0

The PRN Data Field includes x_1 through x_{32} , with each x_n as a 32-bit unsigned integer.

$$\begin{aligned}
 x_1 &= (ax_0 + b) \bmod M \\
 x_2 &= (ax_1 + b) \bmod M \\
 &\dots \\
 x_{32} &= (ax_{31} + b) \bmod M
 \end{aligned}$$



(a) Individual Random Data Block with Header



(b) Concatenated Data Blocks Forming a Data Transmission Sequence

Figure 4-1 -- CubeQuest random data packets and concatenated data stream.

4.4.3 Communications Log

Rules 18.C and 18.G specify that each Team shall supply a cubesat communications log to the Judges to verify competition timing. This log shall contain this minimum set of data:

- UTC time and date for the beginning of the Operating Period

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- UTC time and date for acquisition of signal
- Total time of acquired signal (seconds)
- UTC time and date for the loss of signal/end of Operating Period
- Rest carrier frequency
- Beginning and ending Doppler offsets at a minimum; intermediate values taken at least once per five-minute period are preferred
- Data Rate
- Link Quality (BER, C/N, etc.) estimate
- Total data received when in receiver lock
- Azimuth and Elevation pointing data during the operational period

The log is to be sent in ASCII text format, with read receipt enabled, to the specified e-mail address that the Cube Quest Challenge Administrators will provide to each Team. The log is to be delivered within one hour of the end of operations for the Competition Day. Each Team’s specification for data transferal must be finalized, documented, and approved by the Cube Quest Challenge Administrators at least 30 days prior to spacecraft integration with either the Artemis-1 launch, or the third-party launch vehicle, as appropriate.

4.4.4 Data Packets Wrapping Protocol

Rule 18.D specifies that Teams may choose to wrap Challenge data packets in a convenient protocol for transmission to assist with block accounting and sequencing as long as the Judges can verify that the data was generated by the prescribed algorithm and that the wrapped transmission contains all of the required data. NASA does not wish to specify the specific wrapping protocol that the Team chooses to use. The choice of formatting the transmission protocol is left to the Team to specify. The choice of FEC or ARQ, synchronization, and placement of the competition data packets within the transmission protocol wrapper is left to the Team based on good engineering practice and ease of processing upon reception. The Team must document the wrapping protocol as part of the communications design so that NASA can have insight into the data transmission process being used. The location, length, and format (hex, binary, floating point, or text) of all fields is to be documented in each Team’s transmission specification document. **Note:** any bits for FEC or ARQ will not count towards the data total – only the uncoded bits. Additionally, protocol structures, such as headers, trailers, synchronization markers, and fill data, do not count in the total of the Challenge data tally. The final, documented wrapping protocol details must be approved by the Cube Quest Challenge Administrators at least 30 days prior to spacecraft integration with either the Artemis-1 or the third-party launch vehicle, as appropriate.

Rules 18.F and 18.G specify that the Team shall forward competition data packets, both raw and processed, to NASA within one hour of the end of the operations for the Competition Day.

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The time allows processing to remove transmission artifacts such as duplicates caused by re-transmissions to correct errors. The processed data is to conform to the stream format illustrated in Figure 4-1(b).

4.4.5 Raw Data and Navigation Data Transferal

Each Team shall deliver their raw data in Wireshark/*tcpdump* PCAPNG files captured at the earliest point in their ground system where the data is in Ethernet frames. The actual contents may vary depending on their lower level details, but at a minimum, ground receipt time stamps shall be supplied with the data to help verify the relationship between when the data was sent and when received, and identify the nodes involved with the data collection process.

NASA will work with each team to determine the most efficient means for data transferal, e.g. e-mail or ftp, and file format, e.g. ASCII or binary. Team specification for data formatting and transferal must be finalized, documented, and approved with the Cube Quest Challenge Administrators at least 30 days prior to spacecraft integration with either the Artemis-1 or the third-party launch vehicle, as appropriate.

Rules 22.B and 24.C specify that the Teams must use one of the methods described in the document “Required Navigation Artifacts” for demonstrating operational orbits. The document provided two approaches for supplying the required data: one approach using the DSN and the other using non-DSN ground stations. Team specification for navigation data transferal under this document must be finalized, documented, and approved with the Cube Quest Challenge Administrators at least 30 days prior to spacecraft integration with either the Artemis-1 or the third-party launch vehicle, as appropriate.

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5.0 CHALLENGE DELIVERABLES

The preceding paragraphs specified a number of Challenge deliverables by the Teams and NASA. Table 5-1 lists the NASA deliverables for the Teams along with the Due Date. Similarly, Table 5-2 lists the Team deliverables to NASA along with the Due Date. These deliverables are in addition to documentation required as part of the launch vehicle preparations, e.g., design documents, planetary protection plan, etc.

Table 5-1 -- NASA Deliverables for the Teams

#	Item	Description	Due Date
1	Deployment Time	For those Teams utilizing Artemis-1, this is the time for each Team’s cubesat to be deployed from SLS. This defines the start of the Competition Day for each Team.	As specified in the launch process documentation.
2	Unique team identifier	32-bit unique identifier code for each Team	No later than 1 year prior to launch.
3	Operations Period notification Address	NASA e-mail address to which teams are to submit their operations notice 24 hours prior to the start of each operating period.	No later than 30 days prior to launch.
4	Communications Log Submittal Address	NASA e-mail address to which teams are to submit their communications logs.	No later than 30 days prior to launch.
5	Raw Data Delivery Address and Protocol	NASA and the Team develop the agreed raw data transmission protocol and destination address for delivery.	Raw Data protocol format and delivery address must be approved by Cube Quest Challenge Administrators at least 30 days prior to vehicle integration.
6	Processed Data Delivery Address and Protocol	NASA and the Team develop the agreed processed data transmission protocol and destination address for delivery.	Processed Data protocol format and delivery address must be approved by Cube Quest Challenge Administrators at least 30 days prior to vehicle integration.

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Table 5-2 -- Team Deliverables to NASA

#	Item	Description	Due Date
1	Deployment Time	For those Teams utilizing a third-party launcher, this is the time for each Team’s cubesat to be deployed from that launch vehicle. This defines the start of the Competition Day for each Team.	As specified in the launch process documentation.
2	RF License Permissions	Teams must submit proof of RF license authorization to the Cube Quest Challenge Administrators for both the cubesat and ground station.	At least 30 days prior to launch date or by the date specified by the launch provider, whichever is earlier.
3	Spectral Coordination	Those Teams in close operating relationship will need to coordinate when they will be transmitting to avoid spectral interference. Coordination plan needs to be developed by the Teams.	Coordination Plan must be approved by Cube Quest Challenge Administrators at least 30 days prior to launch.
4	Communications Log Specification Document	Document the format (fields, data format, etc.) for the Team’s communications log.	Communications Log format must be approved by Cube Quest Challenge Administrators at least 30 days prior to integration with the launch vehicle.
5	Data Wrapping Protocol	Document the format (fields, data format, etc.) for the Team’s data transmission protocol from the spacecraft to the ground station.	Data Wrapping protocol format must be approved by Cube Quest Challenge Administrators at least 30 days prior to integration with the launch vehicle.
6	Raw Data Delivery Address and Protocol	NASA and the Team develop the agreed raw data transmission protocol and destination address for delivery.	Raw Data protocol format and delivery address must be approved by Cube Quest Challenge Administrators at least 30 days prior to

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#	Item	Description	Due Date
			integration with the launch vehicle.
7	Processed Data Delivery Address and Protocol	NASA and the Team develop the agreed processed data transmission protocol and destination address for delivery.	Processed Data protocol format and delivery address must be approved by Cube Quest management at least 30 days prior to integration with the launch vehicle.
8	Operations Period notification	Challenge Operating Periods the Team plans to utilize for the next 24 hours, beginning at the start of the next Competition Day.	At least 24 hours in advance of the start of the Competition Day.
9	Communications Log Data	Data log for the Competition Day in the format specified by the Team's Communications Log Specification document.	No later than one hour after the end of operations for a Competition Day.
10	Raw Data Delivery	Raw data packets with transmittal information in the agreed protocol format.	No later than one hour after the end of operations for a Competition Day.
11	Processed Data Delivery	Processed data files in the agreed protocol format.	No later than one hour after the end of operations for a Competition Day.

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Appendix A - Acronyms and Abbreviations

ARQ	Automatic Repeat request
ASCII	American Standard Code for Information Interchange
CCP	Centennial Challenges Program
CCSDS	Consultative Committee for Space Data Systems
DSN	Deep Space Network
FCC	Federal Communications Commission
FEC	Forward Error Correcting
GT	Ground Tournament
NASA	National Aeronautical and Space Administration
NEN	Near Earth Network
NPR	NASA Procedural Requirements
NTIA	National Telecommunications and Information Administration
OPSRUL	Cube Quest Challenge Operations and Rules
PCAPNG	Packet Capture Next Generation Dump File Format
POSIX	Portable Operating System Interface
PRN	Pseudo Random Number
RF	Radio Frequency
SCaN	Space Communications and Navigation
STMD	Space Technology Mission Directorate