

Attachment A
October 6, 2015
Statement of Work
Telemetry Tracking Services for the CYGNSS Mission

1. Objective

This Statement of Work is for procurement of Telemetry Tracking, Recording, and Data Relay Coverage for the NASA Launch Services Program (LSP) in support of Orbital ATK's Pegasus CYGNSS launch vehicle. The CYGNSS launch is currently scheduled for no earlier than (NET) October 17, 2016 from Cape Canaveral Air Force Station (CCAFS).

2. Services to be Provided

Provisions shall be made for a fixed or deployable ground asset(s), and its associated services, that will capture, record, and relay CYGNSS launch vehicle telemetry data in real-time to Hangar AE, CCAFS. The launch vehicle will have two (2) low power S-Band transmitters (Link 2288.5 MHz and Link 2269.5 MHz). The asset(s) shall provide coverage for Third Stage Burnout and four paired spacecraft separation events.

3. Planning

The contractor shall perform the following tasks:

- Determine asset(s) location based upon government provided trajectory, RF characteristics, and sequence of events
- Perform detailed radio frequency (RF) link analyses based on the asset location and the government provided trajectory, RF characteristics, and sequence of events
- Perform a final RF link analysis based upon updated trajectory information provide by NASA LSP
- Choose equipment to meet objectives and provide necessary link margin
- Coordinate with foreign governments for deployment and/or operations of the ground asset(s)
- Coordinate logistical support including shipping, storage, power, and siting of the asset(s)
- Coordinate all integration, testing, operations, and maintenance of the asset(s)
- The contractor shall be responsible for the planning and deployment of telemetry, and voice communications between the proposed asset site and the designated LSP data center
- The contractor shall assume no United States Government (USG) asset(s), including power, are available on the proposed site
- Removal of the asset(s) once the specified launch objectives are met

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- Ensure that all contractor provided/installed systems are certified ready to support per the delivered mission checkout and operation plan no later than (NLT) Launch-21 days
- Provide NASA LSP a complete list of supporting hardware NLT Launch-14 days
- Perform a pre-deployment checkout and review of the telemetry equipment and communications along with all associated documentation at the contractor's site
- Perform a post-deployment checkout and review of the telemetry and communications equipment along with all associated documentation at the proposed deployable site
- Plan for equipment and communications sparing such that the loss of any asset(s) will not compromise the contractor's ability to support any prelaunch testing or launch operations as specified in the Statement of Work. Provide NASA LSP with a list of all spares intended to meet this requirement.
- For proposal submittal, the contractor shall refer to Station Coverage Profile information outlined in Attachment 1: Tracking Station Coverage Profile
- For proposal submittal, the contractor shall refer to RF Link Analysis information outlined in Attachment 2: RF Link Analysis Information
- The contractor shall provide evidence and explain their methodology about meeting NASA LSP's requirements

4. Documentation

The contractor shall perform all required planning and analyses to provide the following items to NASA LSP per Deliverables Table in Section 12 of this SOW:

- Detailed and Final RF link analyses based upon the Orbital ATK projected trajectories
- Mission checkout and operation plan. This checkout and operation plan shall include, but is not limited to:
 - Defined deployment and site operations plan, including mitigation plans
 - Telemetry and voice Communications Plan
 - Testing and mission support procedure
 - Equipment list
 - Telemetry collection equipment configuration and settings
 - Critical spares identification and implementation

5. Equipment

The required telemetry and communications equipment shall include, but is not limited to:

- S-Band RF antenna and associated tracking controller for auto-track and TLE input.
- Redundant S-Band RF receivers
 - with multimode demodulators (FM, Trellis)
 - LHP, RHP and combiner outputs in addition to 70 MHz outputs.
- IRIG-106 Chapter 10 recorder

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- Power generation and distribution equipment
- Telemetry and Voice transport
- Critical spares, along with quantities, such as receiver, recorder, amplifier, power, etc.

NASA LSP reserves the ability to provide additional support equipment to the proposed site (i.e. Wideband Recorder and external USB drives). This equipment will allow NASA LSP to receive and decode the Pegasus telemetry signal on site. Should NASA LSP provide additional support equipment, an equipment list, power specifications, and interface requirements will be provided to the contractor for facility planning purposes.

6. Reviews

The contractor shall attend a post-award kickoff meeting at NASA Kennedy Space Center (KSC).

The contractor shall also support table-top reviews of telemetry collection system settings. Support may be provided via telecom or in person, if available. It is not required for the contractor to travel to attend these meetings.

The contractor shall brief NASA LSP and Orbital ATK NLT Launch-45 days on the mission objectives and provide status on these objectives.

The contractor shall provide support to NASA LSP at the Flight Readiness and the Launch Readiness Reviews should questions arise. The contractor shall provide support via telecom or in person, if available. It is not necessary for the contractor to travel to attend these meetings.

7. Pre-Launch Testing

The contractor shall perform the following pre-launch data flow tests to verify and demonstrate that the specified CYGNSS launch vehicle data can be captured, recorded, and successfully transmitted back to designated NASA LSP site in near real-time:

- L-90 days (Long Loop Test)
 - Demonstrates the asset(s)/equipment to be deployed meet the objectives in the Statement of Work. The equipment used for this test shall be the equipment that will be deployed for support.
 - Demonstrates the asset(s) can simulate receiving and recording Pegasus telemetry data with real-time relay transmissions to the designated NASA LSP site
 - Contractor will be provided Pegasus telemetry data tape/file from a previous Pegasus launch. The contractor shall use this as input to demonstrate that the equipment can acquire, record and relay the Pegasus telemetry data.

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- NASA LSP reserves the option to request the recorded telemetry data be provided to NASA LSP in order to verify compatibility with NASA LSP equipment
- L-21 days after deployment at the proposed site
 - The contractor shall perform a pre-launch functional test with - CYGNSS launch vehicle data (Pegasus)
 - Test shall demonstrate:
 - The contractor's personnel operating the asset(s) have the ability to lock on Pegasus 70 MHz telemetry and record it
 - The contractor can re-transmit the received data real-time to CCAFS
 - NASA will provide the IF Recorder containing the 70 MHz data that will be used for playback purposes
- L-7 days
 - Repeat of the Long Loop Test at the proposed site
- L-3 days
 - Repeat of the Long Loop Test at the proposed site
- L-1 day
 - Repeat of the Long Loop Test at the proposed site
- Day of launch
 - The contractor shall perform a 15 minute closed loop data flow test at approximately 2 hours prior to launch to verify telemetry transmissions and voice communication circuit(s) functionality

At the request of the NASA LSP, the contractor shall provide the NASA LSP post-test data reports for each test within 24 hours of test.

8. Launch Support

The contractor shall coordinate asset(s) responsible for the relay of received Pegasus Launch Vehicle telemetry data in real time from the asset(s) to the designated NASA LSP site. The contractor shall provide personnel at the proposed site to perform the following:

- Operate the provided/installed equipment
- Acquire, receive, record and relay launch vehicle telemetry data in near real-time to the designated NASA LSP data center during the launch
- Provide recorded telemetry to the designated LSP data center within 72 hours of the operation
- Provide AGC and Antenna Elevation and Azimuth data
- The contractor shall provide the NASA LSP post-launch data reports for each launch attempt within 2 weeks of Launch

Note: NASA LSP has the option to provide a representative at the proposed site to monitor operations and to provide asset(s) status to NASA LSP. If NASA LSP exercises their option to deploy NASA LSP telemetry support equipment to the

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proposed site, NASA LSP may provide on-site operational support for that equipment.

9. Communications

The contractor shall establish its own communications support. The contractor shall provide asset(s) status and availability as well as coordinate its asset(s) to support data flow tests and launch.

Communications support shall include all data relay and voice transmissions. Data and voice transmissions shall be extended to the designated NASA LSP site. The contractor shall act as the primary interface to all other commercial entities supporting their effort. A Bit Error Rate Test (BERT) and playbacks of NASA provided Pegasus telemetry are acceptable mechanisms for testing the telemetry relay to the designated NASA LSP site. BERTs shall be an integral part of the pre-launch data flows.

The contractor shall make contact with NASA Flight Operations (NFO) NLT L-4 hours prior to launch to verify all operations are ready to support launch. The contractor shall notify the NFO immediately if there are any anomalies to the telemetry and voice asset(s) not being ready to support launch. Prior to the day of launch this shall be done in writing (email) with a courtesy phone call. The contractor is responsible for providing anomaly resolutions. On day of launch this shall be communicated over designated TBD voice channels.

The contractor shall receive and record the real-time telemetry streams from the CYGNSS launch vehicle until released from service by NASA Flight Operations (NFO).

10. Period of Performance

The period of performance of the basic service is from task order authorization through launch plus ninety (90) days.

11. Technical Points of Contact

- NASA:
 - Samantha Fonder (321-867-2748, samantha.fonder@nasa.gov)
 - Lois Clutter (321-867-2897, lois.m.clutter@nasa.gov)
- Orbital ATK:
 - Steve Hollo (703-948-2265, steven.hollo@orbitalatk.com)
 - Mike Lang (703-948-2263, michael.lang@orbitalatk.com)

12. Requirements

- a. TASK 1- Installation, checkout and certification of all required telemetry collection equipment at the proposed deployable site

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- b. TASK 2 – Development of a Government approved concept of operation for a real-time relay of telemetry from the proposed deployable site to the designated NASA LSP site including test of capability during 5 pre-launch and day of launch data flows. (Deliverable)
- c. TASK 3 – Receive, record, and relay Pegasus telemetry during the CYGNSS launch attempt assuming launch date listed in this SOW, plus 1 day (2 attempts)
- d. TASK 4 – The recorded telemetry shall be placed on tape (or equivalent media) and provided to NASA no less than 24 hours after mission support. (Deliverable)

Deliverables Table:

Item no.	Document/Deliverable/Task	Due Date*	Distribution*
1	Detailed RF Link Analysis Report	NLT L- 9 Months	CO, COR, LSP
2	Mission Checkout and Operations Plan	NLT L- 9 Months	CO, COR, LSP
3	Critical Spares Identification and Implementation Plan	NLT L- 9 Months	CO, COR, LSP
4	Pre-Deployment Checkout Verification/Long Loop Test Demonstration. At Vendor's Site.	NLT L- 90 Days	LSP
5	Final RF Link Analysis Report. NASA LSP to provide updated trajectory information.	L- 60 Days	CO, COR, LSP
6	Prelaunch Functional Test. Performed at Deployable Location. NASA will provide IF recorder containing SimFlight # 4 data for 70 MHz Playback.	NLT L- 21 Days	LSP
7	Installation, checkout and certification of all required telemetry collection equipment at the proposed deployable site. Repeat of Long Loop Test	L- 7 days	LSP
8	Repeat of Long Loop Test	L- 3 days	LSP
9	Repeat of the Long Loop Test at the proposed site	L- 1 days	LSP
10	The contractor shall perform a 15 minute closed loop data flow test at approximately 2 hours prior to launch to verify telemetry transmissions and voice communication circuit(s) functionality	Day of Launch, T-2HRS	LSP
11	Receive, record, and relay Pegasus telemetry during the CYGNSS launch attempt	Day of Launch Plus time	LSP
12	Launch Data Recordings	1 day after launch	LSP
13	Removal and remittance of NASA provided equipment	5 days after launch	CO, COR, LSP

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14	Final Report from Contractor	1 week after Launch	CO, COR, LSP
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*L = Launch

NLT = No Later Than

HRS = Hours

CO = Contracting Officer

COR = Contracting Officer's Representative

LSP = Launch Services Program Representative

13. Options

The options below may be exercised more than once, if necessary.

Option 1: Continued Coverage in the Event of a Launch Delay

Launch delays can be identified anytime after contract award. If the launch is delayed to a date other than the dates designated above, the following additional per day charges will be applicable:

Time Delay Identified	Coverage per Day (\$)*
Authorization to proceed (ATP) to deployment of asset(s)	\$ TBP
Deployment of asset(s) to Launch	\$ TBP

*TBP = To be Proposed

Option 2: Additional Data Flow

Additional Data Flows may be added at any time before launch in the event that more than two data flows are required to verify that data relay between the telemetry station and the receiving facilities are working correctly.

Cost per Data Flow: \$ TBP

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Attachment 1: Tracking Station Coverage Profile

Trajectory Information:

- Information is from the from the Pegasus CYGNSS Performance and Guidance Accuracy Analysis #1 (PGAA-1) trajectory data file depicting time, latitude, longitude and height
- Stage 3 Burn Out (BO) occurs at approximately 464 seconds after lift-off
- The first of the four (4) paired spacecraft separations occurs 300 seconds after Stage 3 BO. The planned timing of the remaining paired separation events will occur in 30 second intervals. Timing for the separation events are Stage 3 Burn Out + 300/30/30/30
 - a. Spacecraft separation event 1 – Stage 3 BO + 300 seconds
 - b. Spacecraft separation event 2 – Spacecraft separation event 1 + 30 seconds
 - c. Spacecraft separation event 3 – Spacecraft separation event 2 + 30 seconds
 - d. Spacecraft separation event 4 – Spacecraft separation event 3 + 30 seconds

CYGNSS.ElapsedSeconds s	CYGNSS.Latitude deg	CYGNSS.Longitude deg	CYGNSS.Height km
460.000000	22.1577680	297.5145946	512.1875898
470.000000	21.8597743	298.0729945	512.1690453
480.000000	21.5591033	298.6304650	512.1039640
490.000000	21.2562652	299.1855428	512.0386622
500.000000	20.9513126	299.7382237	511.9769495
510.000000	20.6442959	300.2885025	511.9146589
520.000000	20.3352384	300.8364181	511.8567781
530.000000	20.0242025	301.3819817	511.7965772
540.000000	19.7112522	301.9251891	511.7365366
550.000000	19.3963549	302.4662101	511.6790261
560.000000	19.0795994	303.0049644	511.6178775
570.000000	18.7610130	303.5415292	511.5569261
580.000000	18.4406340	304.0759368	511.4969880
590.000000	18.1185055	304.6081974	511.4371355
600.000000	17.7946284	305.1384394	511.3784403
610.000000	17.4691500	305.6665214	511.3167021
620.000000	17.1420006	306.1926133	511.2563665
630.000000	16.8132545	306.7167441	511.1949149
640.000000	16.4829452	307.2389325	511.1348496
650.000000	16.1511194	307.7592079	511.0723385
660.000000	15.8177985	308.2776303	511.0133745
670.000000	15.4830382	308.7942254	510.9496699
680.000000	15.1468609	309.3090171	510.8877734
690.000000	14.8093030	309.8220766	510.8270300
700.000000	14.4704129	310.3333999	510.7634919
710.000000	14.1302100	310.8430834	510.7025565
720.000000	13.7887415	311.3511220	510.6401024
730.000000	13.4460400	311.8575721	510.5775810
740.000000	13.1021365	312.3624709	510.5143872
750.000000	12.7570701	312.8658732	510.4520904
760.000000	12.4108678	313.3677983	510.3919758
770.000000	12.0635761	313.8683002	510.3270398
780.000000	11.7152160	314.3673988	510.2669179
790.000000	11.3658369	314.8651684	510.2022908
800.000000	11.0154595	315.3616271	510.1383596
810.000000	10.6641165	315.8568130	510.0782668
820.000000	10.3118488	316.3507823	510.0145054
830.000000	9.9586876	316.8435899	509.9522828
840.000000	9.6046613	317.3352371	509.8899878
850.000000	9.2498045	317.8257808	509.8284444
860.000000	8.8941577	318.3152770	509.7642228
870.000000	8.5377393	318.8037611	509.7039640

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880.0000000

8.1805901

319.2912371

509.6414755

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Attachment 2: RF Link Analysis information

- For the performance of the preliminary RF Link analysis assume a 5 watt PCM/FM S-band downlinks (2288.5 MHz).
- Determine the maximum data rate supportable with a 0dB margin from the support point chosen throughout the required coverage interval.
- Provide an explanation of the equipment used to support the RF Link Analysis
- Third Stage Burn out and Payload Separation events must be covered

- Refer to Attachment 1: Tracking Station Coverage Profile
- Stage 3 Burn Out (BO) occurs at approximately 464 seconds after lift-off. Time spans provided below are approximately +/- 10 seconds of the event.
 - CYGNSS.ElapsedSeconds CYGNSS.Latitude CYGNSS.Longitude CYGNSS.Height
- The first of the four (4) paired spacecraft separations occurs 300 seconds after Stage 3 BO. The planned timing of the remaining paired separation events will occur in 30 second intervals. Timing for the separation events are Stage 3 Burn Out + 300/30/30/30
- Spacecraft separation event 1 – Stage 3 BO + 300 seconds. Time spans provided below are approximately +/- 10 seconds of the event.

s	deg	deg	km
450.0000000	22.4450865	296.9790737	511.3887118
460.0000000	22.1577680	297.5145946	512.1875898
470.0000000	21.8597743	298.0729945	512.1690453

- Spacecraft separation event 2 – Spacecraft separation event 1 + 30 seconds. Time spans provided below are approximately +/- 10 seconds of the event.

s	deg	deg	km
750.0000000	12.7570701	312.8658732	510.4520904
760.0000000	12.4108678	313.3677983	510.3919758
770.0000000	12.0635761	313.8683002	510.3270398

- Spacecraft separation event 3 – Spacecraft separation event 2 + 30 seconds. Time spans provided below are approximately +/- 10 seconds of the event.

s	deg	deg	km
810.0000000	10.6641165	315.8568130	510.0782668
820.0000000	10.3118488	316.3507823	510.0145054
830.0000000	9.9586876	316.8435899	509.9522828

- Spacecraft separation event 4 – Spacecraft separation event 3 + 30 seconds. Time spans provided below are approximately +/- 10 seconds of the event.

s	deg	deg	km
840.0000000	9.6046613	317.3352371	509.8899878
850.0000000	9.2498045	317.8257808	509.8284444
860.0000000	8.8941577	318.3152770	509.7642228