

ANNEX
BETWEEN
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
AND BLUE ORIGIN, LLC
UNDER SPACE ACT UMBRELLA AGREEMENT
NO. 29343, DATED 2/8/2020 (ANNEX NUMBER 4).

ARTICLE 1. PURPOSE

This Annex shall be for the purpose of NASA to collaborate with Blue Origin in the areas of engineering analysis and testing related to precise and safe landing in the development of commercial space transportation systems. The specific areas of collaboration include:

- 1) Technology maturation for hazard sensors including information exchange on GSFC's hazard detection (HD) lidar and Blue Origin lander lidar work. This can include test results, simulation work, analysis, test and design planning and other information.
- 2) High altitude long range lidar testing including test results, flight data correlation analysis results and methodologies, and test planning.
- 3) Construction and error removal from lunar digital elevation maps (DEMs). This can include exchange of information on approaches, potential error sources, and representative maps.
- 4) Providing an option for Blue Origin to acquire a flight prototype of the GSFC HD lidar including pre-work to scope out the path, detailed requirements, and cost of this option.

The legal authority for this Annex, consistent with the Umbrella Agreement, is in accordance with the Space Act, Other Transactions Authority (OTA), 51 U.S.C. § 20113(e).

ARTICLE 2. RESPONSIBILITIES

NASA will use reasonable efforts to:

1. GSFC will support exchange and discussion of requirements, simulations, and drivers for GSFCs HD lidar for planned Blue Origin commercial lunar landers.
 - a. GSFC shall comment on the environmental requirements, sensor concept of operations, and other aspects of integration and test.
 - b. GSFC shall perform simulations on representative Blue Origin trajectories and detailed hazard DEMs. Alternatively, GSFC will provide a compiled tool for Blue Origin to perform the simulations.
2. GSFC will advise and exchange information on GSFC airplane testing with long range altimeters, such as the Land, Vegetation, and Ice Sensor (LVIS).

- a. GSFC shall provide data sets, as available, from other long range lidar testing on airplanes.
 - b. GSFC shall advise on data reduction including calibration, atmospheric correction and modeling, analysis techniques, and terrestrial DEM generation from lidar data such as LVIS. The scheduling and depth of this work will depend on planning around other workloads including other team deployments.
 - c. GSFC shall review the test plans and results of Blue Origin airplane testing, providing comments and recommendations.
- 3. GSFC shall provide limited advising and analysis on lunar surface mapping and alignment of DEMs to images.
 - a. GSFC will review Blue Origin's approach for digital elevation maps.
 - b. GSFC will advise on approaches to align DEMs from LOLA data with imagery from LROC to anchor identified hazards (craters and boulders) with DEMs (slopes).
 - c. GSFC will advise on methods and datasets to obtain improved resolution DEMs at lunar central latitudes.
 - d. GSFC will generate high fidelity DEMs of specified diameter for selected lunar locations. These DEMs will include identified hazards such as craters and boulders. GSFC will advise and comment on DEMs Blue Origin generates for the same locations. The scheduling and depth of this work may require planning around other workloads.
- 4. GSFC shall support the option for building an extra flight test unit of the HD lidar under development at GSFC for the NASA SPLICE program. This will be accomplished in two parts: a baseline work statement and an optional work statement. The part one effort ensures the HD design works with Blue Origin lander, improves the cost and schedule fidelity, and enables a rapid start if the part two option is selected.
 - a. Part one (baseline) –GSFC will define the options and pathways for providing the HD lidar as reimbursable hardware working with the SPLICE program. GSFC will also provide more refined cost and schedule of providing a HD lidar for a Blue Origin space flight test. This test will be strictly data gathering flight opportunity for a Blue Origin lunar missions planned for late 2023 through 2025.
 - b. Part one (baseline) - GSFC will perform a deeper dive into design modifications of hardware to work with Blue Origin lunar landers. This will include integration approach, definition of interfaces for a Blue Origin test flight, performance evaluation, prototypes, long lead items and interface testing.
 - c. Part two (option) – If exercised, GSFC shall implement the plan refined in Part 1 (item 4.a) to build a flight test unit HD lidar. The unit would include long range altimetry channel and would exercise the real-time motion compensation given an IMU data stream from the lander.
 - d. Part two (option) – If exercised, GSFC shall support the HD lidar test unit flight on a Blue Origin lunar lander. GSFC shall qualify the unit for flight

in a do no harm manner (proto-qual is an acceptable option for example). GSFC will support the integration and test with the test objective threshold to record the data and log it for transmission and post-flight analysis.

BLUE ORIGIN will use reasonable efforts to:

1. Blue Origin will support exchange and discussion of requirements, simulations, and drivers for GSFCs HD lidar for planned Blue Origin commercial lunar landers.
 - a. Blue Origin shall provide information on environmental requirements, sensor concept of operations, and other aspects of integration.
 - b. Blue Origin shall provide representative landing trajectories, detailed hazard DEMs, and sensor pointing dispersion models.
2. Blue Origin will exchange information on airplane testing with long range altimeters.
 - a. Blue Origin shall review additional flight test data sets provided by GSFC.
 - b. Blue Origin shall provide plans for its airplane testing and post flight analysis and correlation.
 - c. Blue Origin shall provide data sets from airplane flight tests for GSFC to evaluate and post-process as warranted.
3. Blue Origin will collaborate on lunar surface mapping and alignment of DEMS to images.
 - a. Blue Origin shall provide an overview of its approach for digital elevation maps and for approaches to align DEMs from LOLA data with imagery from LROC to anchor identified hazards.
 - b. Blue Origin will generate high fidelity DEMs of specified diameter for selected lunar locations. These DEMs will include identified hazards such as craters and boulders.
4. Blue Origin shall support the option for building an extra flight test unit of the HD lidar under development at GSFC for the NASA SPLICE program. This will be accomplished in two parts: a baseline work statement and an optional work statement. The part one effort ensures the HD design works with Blue Origin lander, improves the cost and schedule fidelity, and enables a rapid start if the part two option is selected.
 - a. Part one (baseline) – Blue Origin shall support options and pathways for providing the HD lidar as reimbursable hardware working with the SPLICE program.
 - b. Part one (baseline) – Blue Origin shall support a deeper dive into design modifications of hardware to work with Blue Origin lunar landers. This will include integration approach, definition of interfaces for a Blue Origin test flight, performance evaluation, prototypes, long lead items and interface testing.
 - c. Part two (option) – If exercised, Blue Origin shall support the implementation plan refined in Part 1 (item 4.a) to build a flight test unit HD lidar.

- d. Part two (option) – If exercised, Blue Origin shall support the HD lidar test unit flight on a Blue Origin lunar lander.

ARTICLE 3. SCHEDULE AND MILESTONES

The planned major milestones for the activities for this Annex defined in the "Responsibilities" Article are as follows:

Task 1: Hazard detection lidar requirements

- Blue Origin to provide sensor environmental requirements, interface requirements, concept of operations, and representative trajectories. ATP + 1mo
~ATP + 3mo
- GSFC to comment on requirements and deliver simulation results for representative trajectories and DEMs.

Task 2: Long range lidar aircraft testing

- Blue Origin to provide aircraft lidar test plans. ATP + 1mo
- GSFC to provide expertise on aircraft lidar testing data reduction. ATP + 3mo
- GSFC to provide other aircraft lidar data sets. ATP + 3mo
- Blue Origin to provide aircraft lidar test data sets for review.

Task 3: Lunar mapping

- Blue Origin to provide summary of lunar DEM generation. ATP + 1mo
ATP + 3mo
- GSFC to provide recommendations on DEM generation and alignment of DEMs to hazard maps.
- Blue Origin and GSFC to exchange DEMs and hazard maps for selected lunar locations. ATP + 6mo

Task 4: Hazard detection lidar build and test

- Blue Origin and GSFC to mature detailed interface requirements for HD lidar to PDR maturity. ATP + 3mo
- GSFC to provide plan (cost and schedule) for HD lidar build. ~ATP + 6mo
- If exercised, GSFC will support HD lidar build and flight test. ~ATP + 18mo
- If exercised, Blue Origin will support HD lidar build and flight test. ~ATP + 18mo

ARTICLE 4. FINANCIAL OBLIGATIONS

A. Partner agrees to reimburse NASA an estimated cost of \$1.25M total for task 4 and \$285000 per year for tasks 1, 2 and 3. NASA to carry out its responsibilities under this Annex.

Each payment shall be marked with GSFC and ANNEX NUMBER 4.

B. NASA will not provide services or incur costs beyond the current funding. Although NASA has made a good faith effort to accurately estimate its costs, it is understood that NASA provides no assurance that the proposed effort under this Annex will be accomplished for the estimated amount. Should the effort cost more than the estimate, Partner will be advised by NASA as soon as possible. Partner shall pay all costs incurred and have the option of canceling the remaining effort, or providing additional funding in order to continue the proposed effort under the revised estimate. Should this Annex be terminated, or the effort completed at a cost less than the agreed-to estimated cost, NASA shall account for any unspent funds within [insert timeframe, cannot exceed one year] after completion of all effort under this Annex, and promptly thereafter, at Partner's option return any unspent funds to Partner or apply any such unspent funds to other activities under the Umbrella Agreement. Return of unspent funds will be processed via Electronic Funds Transfer (EFT) in accordance with 31 C.F.R. Part 208 and, upon request by NASA, Partner agrees to complete the Automated Clearing House (ACH) Vendor/Miscellaneous Payment Enrollment Form (SF 3881).

ARTICLE 5. INTELLECTUAL PROPERTY RIGHTS - DATA RIGHTS

A. Data produced under this Annex which is subject to paragraph C. of the Intellectual Property Rights - Data Rights Article of the Umbrella Agreement will be protected for the period of four years.

B. Under paragraph H. of the Intellectual Property Rights - Data Rights Article of the Umbrella Agreement, Disclosing Party provides the following Data to Receiving Party. The lists below may not be comprehensive, are subject to change, and do not supersede any restrictive notice on the Data provided.

1. Background Data:

The Disclosing Party's Background Data, if any, will be identified in a separate technical document.

2. Third Party Proprietary Data:

The Disclosing Party's Third Party Proprietary Data, if any, will be identified in a separate technical document.

3. Controlled Government Data:

The Disclosing Party's Controlled Government Data, if any, will be identified in a separate technical document.

4. The following software and related Data will be provided to Partner under a separate Software Usage Agreement:

None

ARTICLE 6. TERM OF ANNEX

This Annex becomes effective upon the date of the last signature below ("Effective Date") and shall remain in effect until the completion of all obligations of both Parties hereto, or February 8, 2025, whichever comes first, unless such term exceeds the duration of the Umbrella Agreement. The term of this Annex shall not exceed the term of the

Umbrella Agreement. The Annex automatically expires upon the expiration of the Umbrella Agreement.

ARTICLE 7. RIGHT TO TERMINATE

Either Party may unilaterally terminate this Annex by providing thirty (30) calendar days written notice to the other Party.

ARTICLE 8. POINTS OF CONTACT

The following personnel are designated as the Points of Contact between the Parties in the performance of this Annex.

Management Points of Contact

NASA Goddard Space Flight Center
Bill Potter
Manager HD Lidar Project
Mail Stop: 436
8800 Greenbelt Road
Greenbelt, Maryland 20771
Phone: 301-356-1218
william.j.potter@nasa.gov

BLUE ORIGIN, LLC
Jessica Curry
Sr. Manager, Subcontracts
8082 Space Commerce Way
Merritt Island, FL 32953
Phone: 253-437-9300 x14527
jcurry2@blueorigin.com

Technical Points of Contact

NASA Goddard Space Flight Center
Bryan Blair
Scientist code 61A
Mail Suite: 61A0
8800 Greenbelt Road
Greenbelt, Maryland 20771
Phone: 301.614.6741
james.b.blair@nasa.gov

BLUE ORIGIN, LLC
Stefan Bieniawski
Principal Technologist for Autonomy &
Guidance, Navigation, and Control
21218 76th Avenue S
Kent, WA 98032-2442
Phone: 206.953.2069
sbieniawski@blueorigin.com

ARTICLE 9. MODIFICATIONS

Any modification to this Annex shall be executed, in writing, and signed by an authorized representative of NASA and the Partner. Modification of an Annex does not modify the terms of the Umbrella Agreement.

ARTICLE 10. SIGNATORY AUTHORITY

The signatories to this Annex covenant and warrant that they have authority to execute this Annex. By signing below, the undersigned agrees to the above terms and conditions.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER

BLUE ORIGIN, LLC

BY: _____
Christyl Johnson
Deputy Director for Technology and
Research Investments

BY: _____
Jessica Curry
Sr Manager Subcontracts

DATE: _____

DATE: _____