ANNEX
BETWEEN
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
AND
RADIAN AEROSPACE, INC.
UNDER SPACE ACT UMBRELLA AGREEMENT NO. 35403 / SAA2-403654
(ANNEX NUMBER ONE)

ARTICLE 1. <u>PURPOSE</u>

This Annex One to the Reimbursable Space Act Umbrella Agreement SAA2-403654 (the "Umbrella Agreement") between Radian Aerospace, Inc ("Partner" or "Radian") and NASA Ames Research Center ("NASA or "NASA ARC") shall be for the purpose of supporting analysis of Radian's launch vehicle and rocket sled.

Under this annex, Radian is interested in leveraging entry systems expertise at ARC in support of designing their proposed launch vehicle, specifically in the areas of aerothermal analysis and thermal protection systems (TPS). Radian is also interested in leveraging high-fidelity computational fluid dynamics (CFD) simulation expertise and capability at ARC in support of assessing the performance capabilities of the rocket sled and predicting the aerodynamic conditions of the separation of the launch vehicle from the carrier sled. These activities support U.S. commercial access to space activities, which is a core Mission for the Agency.

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. <u>RESPONSIBILITIES</u>

A. After receipt of Authority to Proceed (ATP), receipt of deliverables (ROD) from Radian (as defined in the Partner Responsibilities Section) and receipt of advance payment for each task listed below (see Article 4), NASA ARC will use best efforts to provide the following to Radian:

- Initial and rapid aerothermal analysis of their reusable launch vehicle design;
- Analysis of the Thermal Protection System (TPS);
- Rocket Sled CFD modeling, analysis and report; and
- Dynamic separation modeling, analysis and report.

Specifically, NASA plans to provide the Partner with the specific deliverables as described below. Please note that an ROD from Radian will be required for each design cycle.

 #   NASA Project Support Deliverables/Subtasks

  A. Unanchored Analysis Support (rapid analysis to support early design cycle)

    1. Aerothermal Model and Analysis

      Perform Aerothermal analysis using the NASA Ames software tool, CBAERO.

    2. TPS Layout, Sizing, Weights and Temperatures

      Use the results of NASA subtask 1 to perform TPS selection and sizing analysis using the NASA Ames software tools, TPSSizer and the Fully Implicit Ablation and Thermal response program (FIAT). Selected materials, thicknesses, weights and temperatures will be reported.

    3. Margin Evaluation of TPS Sizing

      Use the results of NASA subtasks 1 and 2 to evaluate margins on the aeroheating and TPS response.

B. Anchored Aerothermal and TPS Analysis (More in-depth analysis to support subsequent, more detailed design cycle; Similar to Deliverable A, but includes high fidelity CFD anchoring points)

    4. CFD Database

      Perform High fidelity Computational Fluid Dynamics (CFD) at several conditions in the Partner supplied trajectories to be used to anchor the aerothermal analysis in NASA subtask 5.

    5. Aerothermal Model and Analysis

      Perform aerothermal analysis using the NASA Ames software tool, CBAERO. The resulting database will be anchored to the CFD data created in NASA subtask 4.

    6. TPS Layout, Sizing, Weights and Temperatures

      Use the results of NASA subtask 5 to perform TPS selection and sizing analysis using the NASA Ames software tools, TPSSizer and FIAT. Selected materials, thicknesses, weights and temperatures will be reported.

    7. Margin Evaluation of TPS Sizing

      Use the results of NASA subtasks 5 and 6 to evaluate margins on the aeroheating and TPS response.

C. Aerodynamic CFD Analysis (other analysis in support of rocket sled and dynamic separation)

    8. Initial Look at Rocket Sled Aerodynamics

      Conduct initial CFD simulations of the aerodynamics of the sled, vehicle and track using the commercial software tool, StarCCM+. Simulations at 4 to 6 speeds.

    9. Rocket Sled Aerodynamics – More In-depth

Continue analysis from NASA subtask 8, for more detailed geometry configurations and additional speeds.

10. Initial Look – Dynamic Separation Analysis

Conduct initial CFD simulations of the separation of the launch vehicle from the sled using the commercial software tool, StarCCM+. Simulations will be for 2 final speeds.

11. Dynamic Separation Analysis – More In-depth

Continue analysis from NASA subtask 10, for more detailed geometry configurations and additional speeds.

12. Initial Look at Deflect Control Surface

Conduct a low fidelity (engineering level) first look at deflected control surface aerothermal heating of the launch vehicle using the NASA Ames software tool, CBAERO.

D. Project Support

13. Reports and Presentations

Prepare and discuss reports and presentations with Partner at the completion of every funded tasks.

14. Subject Matter Expert (SME) support

Provide SMEs in the areas of aerodynamic analysis, aerothermal analysis and TPS material for meetings, discussions and consultation.

B. After receipt of Authority to Proceed (ATP), Partner will provide the following to NASA ARC:

- Flight conditions for the launch vehicle; and
- Designs for the rocket sled and launch vehicle.

Partner's responsibilities under this Annex are to be accomplished prior to the start of NASA's corresponding responsibilities. Partner must provide the following inputs for each initiated subtask, which are required inputs for the NASA generated deliverables, and are as follows:

 #   Partner Deliverables

1.   Provide re-entry trajectory data.

Required trajectory data are vehicle velocity, altitude, atmospheric density, angle of attack and slideslip angle as functions of time

2.   Provide launch vehicle outer mold line geometry.

Geometry should be in the form of Computer Aided Design (CAD) files in a format suitable for mesh generation. ProE is preferred, followed by STEP and lastly IGES.

3.   Provide interface temperature requirements.

This information should include any temperature limits of the vehicle structure by vehicle location.

4. Provide launch vehicle structure material and thickness by region of the vehicle.

    This information should be precise (e.g. 5 lb aluminum honeycomb with 0.02" titanium facesheets) or a thermal mass equivalent (e.g. 0.06" titanium).

5. Provide geometry model of the vehicle with deflected surfaces.

    Geometry should be in the form of Computer Aided Design (CAD) files in a format suitable for mesh generation. ProE is preferred, followed by STEP and lastly IGES.

6. Provide details of Rocked Sled configuration and operation.

    Geometry should be in the form of Computer Aided Design (CAD) files in a format suitable for mesh generation. ProE is preferred, followed by STEP and lastly IGES.

ARTICLE 3. <u>SCHEDULE AND MILESTONES</u>

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

I.   NASA DELIVERABLES AND SCHEDULE

Deliverables listed in this Article match the numbering system from the NASA Responsibilities Article and are also referred to as subtasks. Partner's inputs are notated as Receipt of Deliverables ("ROD"). Note that the "Authority to Proceed" (ATP) requires appropriate signatures on this agreement from both Parties and a transfer of funds from the Partner to NASA ARC on a per subtask basis. Further note that the Partner can selectively fund any or all of the deliverables (subtasks) listed in this Article. Should Partner provide ATP and funding out of sequential order, NASA reserves the right to revise the estimated due date. The planned major milestones for the activities for this Annex defined in the "Responsibilities" Article are as follows:

#	NASA Project Support Deliverables/Subtasks	Due Date
A.	Unanchored Analysis Support:	
1.	Aerothermal Model and Analysis	ATP+ROD + 4 weeks
2.	TPS Layout, Sizing, Weights and Temperatures	ATP+ROD + 8 weeks
3.	Margin Evaluation of TPS Sizing	ATP+ROD + 8 weeks
B.	Anchored Aerothermal and TPS Analysis	
4.	CFD Database	ATP+ROD + 14 weeks
5.	Aerothermal Model and Analysis	ATP+ROD + 16 weeks
6.	TPS Layout, Sizing, Weights and Temperatures	ATP+ROD + 20 weeks
7.	Margin Evaluation of TPS Sizing	ATP+ROD + 20 weeks
C.	Aerodynamic CFD Analysis	
8.	Initial Look at Rocket Sled Aerodynamics	ATP+ROD + 6 weeks

9.	Rocket Sled Aerodynamics – More In-depth	ATP+ROD + 16 weeks
10.	Initial Look – Dynamic Separation Analysis	ATP+ROD + 4 weeks
11.	Dynamic Separation Analysis – More In-depth	ATP+ROD + 16 weeks
12.	Initial Look at Deflected Control Surface	ATP+ROD + 10 weeks
D.	Project Support	
13.	Reports and Presentations	ATP+ROD + 104 weeks
14.	Subject Matter Expert (SME) support	ATP+ROD + 104 weeks

II. PARTNER'S DELIVERABLES AND SCHEDULE

Partner is required to provide the follow RODs prior to the initiation of each NASA subtask:

#	Partner Deliverables	Due Date
1.	Re-entry trajectory data	ATP
2.	Launch vehicle outer mold line geometry, CAD	ATP
3.	Interface temperature requirements by launch vehicle location	ATP
4.	Launch vehicle structure material and thickness by region of the vehicle	ATP
5.	CAD model of the vehicle with deflected surfaces	ATP
6.	Details of Rocked Sled configuration (CAD) and operation	ATP

ARTICLE 4. FINANCIAL OBLIGATIONS

A. Partner agrees to reimburse NASA to carry out its responsibilities on a per subtask basis under this Agreement. In no event will NASA transfer any U.S. Government funds to Partner under this Agreement. Payment must be made by Partner in the amounts set forth below for each Subtask in advance of initiation of NASA's efforts on behalf of the Partner for such Subtask.

Partner can selectively fund any or all of the subtasks listed in this Article, which correspond to the NASA Deliverables listed in the previous Article. Partner can also fund any subtask listed in this Annex multiple times in support of multiple design cycles of the Partner's vehicle concept. The estimated cost for one (1) design cycle of each respective Subtask are:

#	NASA Project Support Deliverables/Subtasks	Cost
A.	Unanchored Analysis Support:	
1.	Aerothermal Model and Analysis	$25,000
2.	TPS Layout, Sizing, Weights and Temperatures	$45,000

	3.	Margin Evaluation of TPS Sizing	$10,000
B.		Anchored Aerothermal and TPS Analysis	
	4.	CFD Database	$175,000
	5.	Aerothermal Model and Analysis	$45,000
	6.	TPS Layout, Sizing, Weights and Temperatures	$70,000
	7.	Margin Evaluation of TPS Sizing	$10,000
C.		Aerodynamic CFD Analysis	
	8.	Initial Look at Rocket Sled Aerodynamics	$50,000
	9.	Rocket Sled Aerodynamics – More In-depth	$75,000
	10.	Initial Look – Dynamic Separation Analysis	$30,000
	11.	Dynamic Separation Analysis – More In-depth	$75,000
	12.	Initial Look at Deflected Control Surface	$45,000
D.		Project Support	
	13.	Reports and Presentations	
	14.	Subject Matter Expert (SME) support	$45,000

Each payment shall be marked with Ames, Annex One, SAA2-403654-1.

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 six months 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. <u>INTELLECTUAL PROPERTY RIGHTS - DATA RIGHTS</u>

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 two 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 document.

2. Third Party Proprietary Data:

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

3. Controlled Government Data:

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

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

None.

ARTICLE 6. <u>TERM OF ANNEX</u>

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 three years from the Effective Date, 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. <u>RIGHT TO TERMINATE</u>

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

ARTICLE 8. <u>POINTS OF CONTACT</u>

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

<u>Management Points of Contact</u>

<u>NASA Ames Research Center</u>	<u>Radian Aerospace, Inc.</u>
Matt Holtrust	Jeff Feige
Agreement Manager	Chief Strategy Officer
Mail Stop: 223-3, Room 100	2210 Ilwaco Ave. NE

Moffett Field, CA 94035
Phone: (650) 604-4069
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Renton, WA 98059
Phone: (410) 963-2209
jeff@radianaerospace.com

Technical Points of Contact

NASA Ames Research Center
Kathy McGuire
Aerospace Engineer
Mail Stop: 258-1
Moffett Field, CA 94035
Phone: 650.604.5860
kathy.mcguire@nasa.gov

Radian Aerospace, Inc.
Livingston Holder
Chief Technology Officer
2210 Ilwaco Ave. NE
Renton, WA 98059
Phone: (425)643-3991
livingston@radianaerospace.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 AMES RESEARCH CENTER

RADIAN AEROSPACE, INC.

BY:_____

Huy K. Tran
Director of Aeronautics

BY:_____

Curtis Gifford
COO Radian Aerospace

DATE:_____

DATE:_____12/21/2021_____