

ANNEX
BETWEEN
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
AND IMPULSE SPACE
UNDER SPACE ACT UMBRELLA AGREEMENT
NO. 37684, DATED 11/16/2022 (ANNEX NUMBER 2).

ARTICLE 1. PURPOSE

This Annex shall be for the purpose of The purpose of this Annex is to allow the National Aeronautics and Space Administration's (NASA) Orbital Debris Program Office (ODPO), located at Johnson Space Center (JSC), within the Astromaterials Research and Exploration Science (ARES) division (hereinafter referred to as "ODPO"), to provide a computer-based analysis of the reentry survivability of Impulse Space's spacecraft using ODPO's Object Reentry Survival Analysis Tool (ORSAT) software. In addition, this SAA will allow NASA's Hypervelocity Impact Technology (HVIT) group (hereinafter referred to collectively as "HVIT"), also located at JSC within the ARES division, to provide Impulse Space with micrometeoroid and orbital debris (MMOD) risk assessment of Impulse Space's spacecraft using the Bumper software. These activities are consistent with NASA's mission to take steps to preserve the near-Earth space environment, in accordance with the National Space Policy and the U.S. Government's Orbital Debris Mitigation Standard Practices, and to mitigate the risk to human life and space missions due to orbital debris and meteoroids (NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments, NPR 8715.6B, 2017). ODPO will provide the analysis of the survivability of the Impulse Space spacecraft assuming a natural decay from a near-circular orbit. ODPO will provide the analysis results, including a list of component objects which are assessed to survive reentry along with the debris casualty area for components which have a kinetic energy of more than 15 joules. Combining this information with an orbital inclination and the year of reentry, Impulse Space will be able to calculate the risk of human casualty due to surviving components. The U.S. Government Orbital Debris Mitigation Standard Practices and NASA Standard 8719.14C require that the risk of human casualty be less than 1 in 10,000 for each spacecraft reentry. The ORSAT code is the state-of-the-art algorithm for calculating the survivability of reentering spacecraft, rocket bodies, and debris. It uses integrated trajectory, atmospheric, aerodynamic, aerothermodynamic, and thermal/ablation models to calculate the reentry survivability. ODPO will test and characterize Impulse Space-proprietary materials, such as carbon fiber-reinforced plastic (CFRP) or glass fiber reinforced plastic (GFRP) using a plasma torch facility. The plasma torch testing results will be used to generate a custom demise model for CFRP and GFRP materials and allow a more accurate reentry demise analysis to be conducted. The NASA JSC HVIT group uses state-of-the-art MMOD analysis codes supported by hypervelocity impact test results to assess effects of MMOD impacts on spacecraft shielding, pressure vessels, hardware, and structure materials. The Bumper 3 code is the latest version of the computer analysis tool to assess MMOD risk for NASA spacecraft. Bumper 3 is the NASA approved code to perform MMOD risk assessments for the International Space Station, Orion crew vehicle, extravehicular activity suits, and other NASA spacecraft and projects. Bumper 3 is

maintained by the HVIT group and contains ballistic limit equations for a wide variety of spacecraft hardware components and shields that have been derived from thousands of hypervelocity impact tests performed by NASA/HVIT over many years. The combinations of HVIT capabilities in MMOD impact risk assessments, MMOD shielding design expertise, hypervelocity impact test evaluation, and a broad range of shielding and hardware performance equations (i.e., ballistic limit equations) is not available in the commercial world. Providing support to Impulse Space will help with on-going monitoring and analysis of the orbital debris population in Earth orbit and mitigating orbital debris growth and risk from reentries of spacecraft and upper stages. To that end, utilizing its unique skillset in orbital debris environments, NASA may advise and assess Impulse Space on systems engineering and integration, and preliminary concepts for spacecraft design, testing, and mission operations. NASA personnel will also advise, as needed, Impulse Space on design and material options that affect spacecraft risk based on NASA personnel's extensive knowledge on the orbital debris population and spacecraft survivability from MMOD impact that may affect design and operations. NASA, as needed, will provide additional review and expert analysis of iterative changes to the spacecraft's design to ensure continued improvement in risk. .

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

A. NASA JSC will use reasonable efforts to:

NASA JSC ODPO:

1. Provide advice and oversight on testing parameters for composite materials demisability and strength testing using material samples provided by Impulse Space
2. Perform plasma torch testing on Impulse Space-provided samples at the University of Texas Austin Inductively Coupled Plasma Torch facility
3. Deliver a test report summary to Impulse Space based on the test parameters and results.
4. Develop an Impulse Space spacecraft break-up model based on experimental plasma tests and components for the vehicle using the ORSAT software assuming a natural decay of Impulse Space's spacecraft from a near-circular orbit.
5. ORSAT analysis to predict the reentry survivability of the updated spacecraft at different orbital inclinations on an as needed basis.
6. Provide debris footprints for surviving debris of the spacecraft using new configuration
7. Deliver a 1-2 page summary to Impulse Space of re-entry analysis results and debris casualty assessment (DCA) for the survivability of the entirety of the spacecraft based on each of the components at the requested orbital inclinations to include the altitude at which each of the components burn-up and an assessment of human casualty risks.
8. Deliver a detailed report on the assessment of the Impulse Space spacecraft. The report will include sections on ORSAT method of analysis, including the physics and assumptions of each module, and descriptions and plots of the assessment result.
9. Participate in meetings with Impulse Space via teleconference to discuss the findings in summary reports on an as needed basis.
10. Participate in bi-weekly Technical Interchange Meetings with Impulse Space via

teleconference to discuss composite material test preparations.

NASA JSC HVIT:

- 11. Provide training on the Bumper-code software.
- 12. Provide micrometeoroid and orbital debris (MMOD) impact and penetration failure risks for an Impulse Space spacecraft using Bumper-code.
- 13. Discuss study progress with Impulse Space at regularly scheduled teleconferences.

B. Partner will use reasonable efforts to:

- 1. Provide relevant mission-related requirements.
- 2. Provide NASA with all agreed upon information needed to develop a spacecraft model for ORSAT and Bumper-code assessments.
- 3. Support agreed upon Technical Interchange Meetings (TIMs) either in-person or via teleconference between Impulse Space and other NASA or non-NASA third-party participants.
- 4. Provide ODPO prepared composite material samples for experimental testing in plasma torch facility
- 5. Invite NASA subject matter expertise (SME) personnel to participate at formal reviews related to orbital debris and overall flight readiness

ARTICLE 3. SCHEDULE AND MILESTONES

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

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| 1. Impulse Space will host Technical Interchange Meetings with NASA to discuss analysis progress and advise on potential design changes to mitigate spacecraft risk | Weekly or as-needed |
| 2. HVIT will provide Bumper-code training to Impulse Space | 12 weeks after "Effective Date" of the Agreement |
| 3. ODPO will provide DAS training to Impulse Space | Starting at "Effective Date" of the Agreement, as-needed |
| 4. Impulse Space will provide to NASA all information necessary to perform analysis required in the performance of NASA responsibilities under this Space Act Agreement (SAA) Annex, to include material definitions for any non-standard material cases that are not produced or handled by DAS/ORSAT/Bumper by default. | One week after "Effective Date" of the Agreement. Authority to proceed shall occur once ODPO and HVIT receive payment from Impulse Space. |
| 5. HVIT will perform Bumper analysis to assess MMOD risk of the Impulse Space spacecraft and provide results in PowerPoint format. | 12 weeks after information and data |

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| 6. ODPO will perform ORSAT analysis to predict the reentry survivability of the Impulse Space spacecraft at the requested orbital inclinations. | specified in milestone 4 are delivered to NASA 12 weeks after complete information package delivery as described in milestone 4 |
| 7. ODPO will provide a 1-2 page summary to Impulse Space of re-entry analysis results and debris casualty assessment for each of the provided components at the requested orbital inclinations. | 12 weeks after complete information package delivery as described in milestone 4 |
| 8. ODPO will provide a detailed report on the reentry casualty risk assessment. | 16 weeks after complete information package delivery as described in milestone 4 |
| 9. NASA and Impulse Space to participate in a follow-up meeting via teleconference to discuss analysis findings and any further iterations of the spacecraft design. | On an as-needed basis |
| 10. Impulse Space will provide material samples to ODPO for testing in plasma torch facility | 6 weeks after "Effective Date" of Agreement |
| 11. ODPO will perform material testing in plasma torch facility. | Depends on facility availability |
| 12. ODPO will provide Impulse Space with a test report detailing material demisability findings observed in plasma torch testing of Impulse Space-provided material samples. | 6 weeks after completion of testing |

ARTICLE 4. FINANCIAL OBLIGATIONS

A. Partner agrees to reimburse NASA an estimated cost of \$98,022.37 for NASA to carry out its responsibilities under this Annex. Each payment shall be marked with JSC 37684 Annex 2.

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 6. 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 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 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: N/A

ARTICLE 7. 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 one year 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 8. RIGHT TO TERMINATE

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

ARTICLE 9. 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 Lyndon B. Johnson Space Center
Jer-Chyi (J.-C.) Liou, PhD
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2101 NASA Parkway
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Fax: 281-483-1573
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Impulse Space
Nicholas Simon
Mission Manager
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Technical Points of Contact

NASA Lyndon B. Johnson Space Center
Chris Ostrom
Safety Lead
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Eric L. Christiansen
JSC-XI5 Branch Chief and NASA HVIT Technical Lead
Hypervelocity Impact Technology (HVIT) Team
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2101 NASA Parkway
Houston, Texas 77058
Phone: 832-964-8599
Eric.L.Christiansen@nasa.gov

ARTICLE 10. 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 11. 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
LYNDON B. JOHNSON SPACE
CENTER

IMPULSE SPACE

BY: _____
Burt Laws
Director, Exploration Architecture
Integration and Science

BY:  _____
Eric Romo
Chief Financial Officer

DATE: _____

DATE: 1/22/2024 _____