ANNEX NO. 4
BETWEEN
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GLENN RESEARCH CENTER
AND
THE BOEING COMPANY
UNDER NON-REIMBURSABLE SPACE ACT UMBRELLA AGREEMENT
NO. 35361, DATED 5/4/2022
FOR
EVALUATION OF RTM385 POLYIMIDE STITCHED COMPOSITES
BY RESIN FILM INFUSION

ARTICLE 1. PURPOSE

This Annex shall be for the purpose of evaluating National Aeronautics and Space Administration NASA Glenn Research Center (NASA or NASA GRC)'s developed melt-processable polyimide resin (RTM385) for infusion by The Boeing Company (Boeing or Partner) into stitched carbon fiber preforms and assessing the resultant physical properties of RTM385 stitched composites for potential airframe application. This activity will benefit NASA GRC by leveraging Boeing's proprietary resin film infusion (RFI) fabrication technique. This activity will also benefit Boeing by allowing use of NASA GRC's novel high temperature polyimide resin to advance the use temperature of stitched polyimide composites in the aerospace field.

Traditionally, epoxy and bismleimide (BMI) resins have been used extensively as composites in airframe components. However, the use temperatures of epoxy and BMI are limited to long-term 177°C and 232°C application, respectively. In the past, polyimide composites are very difficult to be fabricated into composites, because it requires the use of high boiling solvents exceeding 200°C, which are very difficult to remove afterwards. The invention of solvent-free, melt-processable polyimide resins, such as RTM385, allows the resin to be processed in the melt-state without solvent and amenable to low-cost resin transfer molding (RTM) and resin film infusion (RFI). Furthermore, the thermosetting RTM385 can be infused into carbon fiber preforms at 280°C and then cured at 370°C, followed by post-cure to afford a polyimide composite with a glass transition temperature (T_g) of 385°C, which is a breakthrough in high temperature composites with above 300°C capability. This collaborative effort between Boeing and NASA will allow the RTM385 polyimide components to be more durable than the conventional epoxy and BMI parts for higher temperature aerospace application.

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 will use reasonable efforts to:

1. Provide Boeing with 12 pounds (lbs.) of aerospace grade RTM385 resin powder as government furnished product for resin film infusion (RFI).

2. Provide Boeing with isotropically stitched carbon fiber preforms, consisting of sixteen (16) layers of T650-35, 8HS carbon fabrics with a total of at least four (4) 10" by 31" panels as government furnished product for RFI.

3. Perform the following two (2) items listed as (a) and (b) below on a small portion of a composite panel provided to NASA by Boeing after composite fabrication (before post-cure) and after post-cure:
   a) Determine glass transition temperature (T_g) before and after post-cure by Dynamical Mechanical Analysis (DMA), and
   b) Determine void content by acid digestion method before and after post-cure.

B. Boeing will use reasonable efforts to:

1. Provide personnel, technical expertise, and fabrication tools necessary for composite fabrication by RFI as well as subsequent characterization and mechanical testing.

2. Infuse 4 stitched panels of 10" by 31" carbon fiber preforms (six (6) mm thick) with the RTM385 imide resin by RFI.

3. Verify the acceptable quality for each panel by ultrasonic C-Scan after composite fabrication (before post-cure) and after post-cure for each panel.

4. Provide a small portion composite panel before and after post-cure to GRC to determine the glass transition temperature (T_g) by Dynamical Mechanical Analysis (DMA) and void contents by acid digestion.

5. Verify the acceptable quality of each panel before and after post-cure by photomicrographs.

6. Conduct un-notched (UNC) and open hole compression (OHC) tests on the stitched composites after post-cure for three (3) temperatures (room temperature, 450°F, 550°F) and perform six (6) repeats per each test at the three (3) temperatures.

7. Conduct thermal cycling on one set of panels from -65°F to 450°F and another set of panels from -65°F to 550°F, up to 2000 cycles using thermal cycling chambers at Boeing, and conduct micro-crack analysis at 400, 800, 1200, 1600, and 2000 cycles by photomicrographs. Examine for micro-cracks at 50X on specimens.

8. Prepare a final report for submission to NASA GRC.

9. Provide for a single point of contact for Annex development and operations.

ARTICLE 3. SCHEDULE AND MILESTONES

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

1. NASA GRC to deliver RTM385 resin and stitched preforms to Boeing.	Approximately 1 month after Effective Date.
2. Boeing to complete infusion of RTM385 resins into 4 panels of T650-35 stitched carbon fiber preforms (six (6) mm thick).	On or about February 2024.
3. Boeing to inspect the quality of the stitched composites after fabrication by ultrasonic C-scans and photomicrographs before and after post-cure.	On or about March 2024.
4. Boeing to complete mechanical testing for un-notched and open-hole compression tests at room temperature, 450°F, and 550°F after post-cure and perform six (6) repeats at each temperature.	On or about July 2024.
5. Boeing to complete thermal cycling for one set of panels from -65°F to 450°F and another set from -65°F to 550°F, and conduct microcrack analysis by micrographs at 400, 800, 1200, 1600, and 2000 cycles. Examine for microcracks at 50X on specimens.	On or about August 2024.
6. Boeing to complete final report and submit to NASA GRC.	On or about October 2024.

ARTICLE 4. FINANCIAL OBLIGATIONS

There will be no transfer of funds between the Parties under this Agreement and each Party will fund its own participation. All activities under or pursuant to this Agreement are subject to the availability of funds, and no provision of this Agreement shall be interpreted to require obligation or payment of funds in violation of the Anti-Deficiency Act, (31 U.S.C. § 1341).

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 one (1) year.

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 two (2) 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. 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
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Materials and Structures Division Chief
Mail Stop: 49-1
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Technical Points of Contact

NASA
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The Boeing Company
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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
GLENN RESEARCH CENTER

BY: TIMOTHY MCCARTNEY Digitally signed by TIMOTHY MCCARTNEY Date: 2023.08.07 20:12:37 -04'00'
Timothy P. McCartney
Director, Aeronautics

DATE: 8/7/23

THE BOEING COMPANY

BY: Allyson.M.Kutterer.2417428 Digitally signed by Allyson.M.Kutterer.2417428 Date: 2023.07.17 12:27:59 -05'00'
Allyson Kutterer for Adam Iwanow
Contract Management Specialist

DATE: 7/17/2023