



## Certified Additive Manufacturing for Aircraft Interiors

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### THE CERTIFICATION CHALLENGE

Additive manufacturing (AM) processes and materials pose real benefits for the aerospace industry through manufacturing, performance and supply chain improvements. However, certification of AM aircraft parts is currently a challenging, if not ambiguous endeavor for aerospace companies. The primary reason is the lack of an established certification roadmap and qualified materials.

Companies may be experienced with AM but aren't aware of the critical aspects of this technology as it relates to aircraft certification. The result is a lack of specific guidelines and specifications needed to satisfy the certification communities. Then there are those familiar with the certification process but still see it through a traditional manufacturing lens, and lack the experience needed to translate the critical elements to the AM world.

Also lacking is a database of AM material properties that engineers can use to design and develop aircraft parts using the AM process. The absence of material property data means aircraft companies are left to develop this information on their own, a process that can be extremely expensive and time consuming. Consequently, companies that assume this challenge and develop their own data typically view it as proprietary information, which isn't shared with the broader aerospace community. This creates an environment where all industry participants are forced to create their own data and processes, resulting in variability and a lack of material and process standards.

### THE SOLUTION

In response to this challenge, Stratasys worked together with the aerospace and certification communities to foster a collective understanding of what's needed to create a certification path for additively manufactured parts supported by all parties. To that end, Stratasys developed the Aircraft Interior Certification Solution (AICS). It includes a specially configured Fortus 900mc™ Production System to ensure consistent, reliable build results, and a design allowables dataset for FDM® ULTEM™ 9085 resin material. This product gives aerospace companies the material, process and standards needed to develop AM parts for aircraft installation.

The design allowables, developed using the NCAMP (National Center for Advanced Materials Performance) process with FAA oversight, will reside in the public domain, accessible to any aerospace company. Stratasys provides the certified ULTEM 9085 resin material, the production system configuration and the support necessary to qualify any Fortus 900mc to perform equivalency to the original dataset.

## WHAT'S INCLUDED

The AICS product consists of the following components:

- Material and process specifications
- Certified ULTEM 9085 resin material
- Aircraft Interiors Configuration Fortus 900mc (or upgrade)
- B-Basis design allowables dataset
- Process guidance on system qualification for equivalency tests

## Material and Process Specifications

The Material Specification governs the production of raw ULTEM 9085 resin and its conversion to filament. It focuses on the critical characteristics of upstream raw stock to ensure a high-quality material is provided to customers. A combination of in-line and post-processing inspection techniques, following quality standards set by the extrusion industry, are used to convert incoming material into reliable, high-performing feedstock for Stratasys 3D printers.

The Material Specification was audited by major aerospace OEMs in addition to NIAR (National Institute of Aviation Research) and the FAA. These successful audits provide confidence that the install base receives high-quality feedstock and helps address major areas of concern for final part quality that are a challenge for other AM processes and suppliers to demonstrate.

The Process Specification controls the entire workflow from material handling through part removal, inspection and delivery for installation using ULTEM 9085 resin. The Process Specification also provides the information needed to ensure the Fortus 900mc operates within specification for achieving and maintaining printer qualification. This document was the result of several years of parameter isolation and validation to strike a balance between unlimited design freedom and stable, repeatable part production. Both of these documents provide the specifications and guidance necessary to attain consistent results and allow documented traceability from the part back to the raw material production lot.

Both of these specifications are available from Stratasys and NCAMP.

## Certified ULTEM 9085 Resin Material

A key part of the Aircraft Interior Certification Solution is certified ULTEM 9085 resin. This high-performance thermoplastic possesses an ample strength-to-weight ratio and good high-temp operating characteristics compared with other resins. It's also FAR 25.853 compliant for flame, smoke and toxicity characteristics.

Certified ULTEM 9085 resin filament comes with complete documentation to provide users with full traceability from the raw resin to the filament to the finished part. A certificate of analysis for the raw resin includes test results for a number of material properties. Test methods are in accordance with FAR 25.53 and ASTM standards. This document also identifies the material batch number.

Stratasys provides a Certificate of Analysis on the filament that's produced from the raw material. It identifies the Stratasys test results for pull force, moisture content and melt flow. This document reflects the Sales Order Number, Stratasys manufacturing lot number and the SABIC (supplier) resin lot number.

A Stratasys Certificate of Production Conformance specifies that the filament is manufactured per established specifications and provides material identification information, including filament spool lot number.

# CERTIFIED ADDITIVE MANUFACTURING FOR AIRCRAFT INTERIORS

The information contained in these documents form a complete chain of traceability from the raw ULTEM 9085 resin pellets to the manufactured FDM filament spool.

**Product Quality Documentation**  
Certificate of Production Conformance

This is to certify that the FDM material(s) listed below were manufactured in accordance with the following specifications, as applicable per product type:

107988-0001 Assembly Requirements Document, Canister, Fortus  
205665-0001 Assembly Requirements Document, Cartridge, 3DP

Part Number
Serial Number
Description
Manufacturing Date
*Spool lot number

\*Stratasys maintains lot specific traceability to supplier raw resin lots.

Troy Loehrs / Ran Barshesht  
Materials Production Managers

Luanne Eisenschank / Koren Cohen  
Quality Managers

Part Number: 109451-0001  
Revision: D  
Certificate of Conformance

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CAGE code: 1GKB4

**Product Quality Documentation**

Stratasys Element Lot Number MfgLot	Customer Sales Order Number SONum	Stratasys Part Number PartNum	Material Designation, Grade, and Class RawMatInfo
Latest Raw Resin Lot Number RawLotNum	Date Manufactured MFGDate	Number of spools shipped (20 to 24) QtyShipped	Shipped from Stratasys Eden Prairie

ULTEM® is a registered trademark of SABIC or @SABIC.

This is to certify that the FDM material(s) that belong to the Sales Order Number stated in the above table meet the requirements of the following specification(s), as applicable per product type:

300000-0001 | Aerospace Filament Specification

No changes in product formulation, raw materials, basic methods of manufacture, or plant site have occurred since the material was qualified.

Properties	Test Method	Unit	Requirements	Stratasys Results				
Full Factor	-	lbs.	Full force spikes less than or equal to 3.75 lbs**	###				
Molecular Weight	ASTM D 2191	%	< or = 0.01%	###				
Melt Flow	ASTM D 1738	g/10 min	MFRReq	<table border="1"> <tr> <th>Beginning of Run</th> <th>End of Run</th> </tr> <tr> <td>###</td> <td>###</td> </tr> </table>	Beginning of Run	End of Run	###	###
Beginning of Run	End of Run							
###	###							

\*\*Full force spikes up to 3.75 lbs are acceptable provided they meet the following criteria: length of spike above 3.75 lbs does not exceed 3 feet; length of spike above 2.75 lbs does not exceed 1 foot.

Troy Loehrs – Materials Production Manager  
Luanne Eisenschank – Quality Manager  
400337-0001 | Rev. C

**Certificate of Analysis**

Certificate Type: Insp. certificate "3.1" EN 18204  
Date printed: 11/15/2016

Blank

Shipped from details:

**APPROVED**  
By Matt Schutts at 11:33 am, Nov 29, 2016

Material Number: 20021900  
Material Description: 9085-1100-OCT-00-00  
Material Group: ULTEM® resin  
Batch Number: 000243171

Characteristic	Unit	Value	Lower Limit	Upper Limit	Inspection Method
F.A.R. 25.853	-	Pass	-	-	FAR 25.853
DRP TIME	-	Pass	-	-	FAR 25.853
EXTINGUISHING TIME, 600	s	1	-	5	FAR 25.853
FAA FLAME BURNING LENGTH	inch	3.8	-	5.0	FAR 25.853
FLEXURAL MODULUS @ 6MM	lb/in <sup>2</sup>	402670	330000	-	ASTM D790
FLEX STRENGTH @BREAK @ 6MM	lb/in <sup>2</sup>	17648.7	12000.0	-	ASTM D790
MANUFACTURE DATE	-	161026	-	-	SABIC
ABS SMOKE DENSITY	#	18.5	50	-	FAR 25.853
HEAT RELEASE 2MIN, KW-MIN/M2	W/m <sup>2</sup>	27	55	-	FAR 25.853
HEAT RELEASE PEAK	W/m <sup>2</sup>	50	55	-	FAR 25.853
SPECIFIC GRAVITY	g/cm <sup>3</sup>	1.269	1.140	1.520	ASTM D792
TENSILE MODULUS	lb/in <sup>2</sup>	379172	360000	-	ASTM D638
TS YIELD 5MMMIN TYPE I	lb/in <sup>2</sup>	12514.8	11000.0	-	ASTM D638
TS MINIMUM INDIVIDUAL TYPE I	lb/in <sup>2</sup>	377267	280000	-	ASTM D638
TS MINIMUM INDIVIDUAL TYPE II	lb/in <sup>2</sup>	12458.0	8800.0	-	ASTM D638
MFR 250°C @ 7K3	g/10min	8.7	6.5	11.0	ASTM D1238

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Examples of Certificates of Analysis and Conformance

## Aircraft Interiors Configuration Fortus 900mc

Another foundational element of the AICS product is the Aircraft Interiors Configuration Fortus 900mc. This specially configured configuration is needed to produce consistent, reliable build results with certified ULTEM 9085 resin. It is available as a newly purchased production system or as a hardware and software upgrade to existing Fortus 900mc Systems.

Using an enhanced material deposition process, the Aircraft Interiors Configuration Fortus 900mc provides very consistent production results and reduces variability from build to build and system to system. This supplies the mechanical property repeatability necessary to demonstrate equivalency to the design allowables. In addition, this configuration results in an increased ultimate tensile strength of the ULTEM 9085 material, compared to test results on the standard Fortus 900mc configuration.

## B-Basis Design Allowables

The establishment of the material properties dataset (B-Basis design allowables) provides another critical piece of the certification solution. NCAMP, a division of NIAR, develops this data and works with the FAA and industry partners to test and qualify aerospace materials. The test results will be stored in a materials database, accessible to the public.

To develop this dataset, a comprehensive, FAA-reviewed test plan was established by NCAMP. The test plan comprised the production of 4700 test coupons made from ULTEM 9085 resin, sourced from multiple material lots. The coupons were produced on several different Fortus 900mc 3D Printers at multiple locations to account for variability in the material, printers and printer location. The specific material properties tests and methods are shown in the following tables.

## CERTIFIED ADDITIVE MANUFACTURING FOR AIRCRAFT INTERIORS

The following material properties are tested for each of three lots of material:

Property	Method
Flammability Drip Time	FAR 25.853
Flammability Extinguishing Time	FAR 25.853
Flammability Burn Length	FAR 25.853
NBS Smoke and Density	FAR 25.853
Heat Release Peak	FAR 25.853
Specific Gravity	ASTM D792
Flexural Strength and Modulus	ASTM D790
Tensile Strength and Modulus	ASTM D638 (Type I)
MFR 295°C @ 6.7KG	ASTM D1238

In addition to these tests, a subset of coupons from each 3D production system and each lot is tested to determine the following properties:

Property	Condition/Method*
Thickness	ASTM D3171-11/or applicable mechanical test method.
Density	ASTM D792-08
Photomicrograph	CP6101 and CP6102
CTE by TMA	ASTM D228/E831
Glass Transition Temperature, T <sub>g</sub> by DMA flexural loading	Dry and Wet – ASTM D7028

\* Where the applicable standard allows variations in specimen form or test method, the specific parameters to be used will be specified in the test work instructions and reported in the final test report.

# CERTIFIED ADDITIVE MANUFACTURING FOR AIRCRAFT INTERIORS

Another subset of coupons from each system and test lot is tested to determine the following material properties:

Test Type	Test Type (5)	Property	Number of Lots x Number of Machines x Number of Coupons		
			Test Temperature/Moisture Condition		
			CTD	RTD	ETW1
OHT	ASTM D5766 Open Hole Tension (1) X	Strength	3x2x4	3x2x4	3x2x4
OHT	ASTM D5766 Open Hole Tension (1) Y	Strength	3x2x4	3x2x4	3x2x4
OHT	ASTM D5766 Open Hole Tension (1) Z	Strength	3x2x4	3x2x4	3x2x4
OHT	ASTM D5766 Open Hole Tension (1) Z (45)	Strength	3x2x4	3x2x4	3x2x4
FHT	ASTM D6742 Filled Hole Tension (2) X	Strength	3x2x4	3x2x4	3x2x4
FHT	ASTM D6742 Filled Hole Tension (2) Y	Strength	3x2x4	3x2x4	3x2x4
FHT	ASTM D6742 Filled Hole Tension (2) Z	Strength	3x2x4	3x2x4	3x2x4
FHT	ASTM D6742 Filled Hole Tension (2) Z (45)	Strength	3x2x4	3x2x4	3x2x4
OHC	ASTM D6484 Open Hole Compression (1) X	Strength		3x2x4 (4)	3x2x4
OHC	ASTM D6484 Open Hole Compression (1) Y	Strength		3x2x4 (4)	3x2x4
OHC	ASTM D6484 Open Hole Compression (1) Z	Strength		3x2x4 (4)	3x2x4
OHC	ASTM D6484 Open Hole Compression (1) Z (45)	Strength		3x2x4 (4)	3x2x4
FHC	ASTM D6742 Filled Hole Compression (2) X	Strength		3x2x4	3x2x4
FHC	ASTM D6742 Filled Hole Compression (2) Y	Strength		3x2x4	3x2x4
FHC	ASTM D6742 Filled Hole Compression (2) Z	Strength		3x2x4	3x2x4
FHC	ASTM D6742 Filled Hole Compression (2) Z (45)	Strength		3x2x4	3x2x4
SSB	ASTM D5961 Single Shear Bearing (3) X	Strength & Deformation		3x2x4	3x2x4
SSB	ASTM D5961 Single Shear Bearing (3) Y	Strength & Deformation		3x2x4	3x2x4
SSB	ASTM D5961 Single Shear Bearing (3) Z	Strength & Deformation		3x2x4	3x2x4
SSB	ASTM D5961 Single Shear Bearing (3) Z (45)	Strength & Deformation		3x2x4	3x2x4
IZOD Impact	ASTM D256 IZOD Pendulum Impact X	Impact Resistance		3x2x4	
IZOD Impact	ASTM D256 IZOD Pendulum Impact Y	Impact Resistance		3x2x4	
IZOD Impact	ASTM D256 IZOD Pendulum Impact Z	Impact Resistance		3x2x4	
IZOD Impact	ASTM D256 IZOD Pendulum Impact Z (45)	Impact Resistance		3x2x4	

(1) Open-hole configuration: 0.25 inch hole diameter, 1.5 inch width.

(2) Filled-hole test configuration: 0.25 inch diameter, see section 2 NTP AM-P-001 document for fastener callout, 1.5 inch width.

(3) Single shear bearing test configuration: 0.25 inch hole diameter, 1.5 inch width, see section 2 of NTP AM-P-001 document for fastener callout, e/D=3, ASTM D5961-08 Procedure C.

(4) Back-to-back strain gages needed on the first two specimens. If no buckling is observed, the remaining modulus specimens will require strain gage on one side of the specimens only.

Appropriate extensometer may be used in place of the strain gage.

(5) All holes will be drilled/reamed by machine.

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Finally, a set of test coupons is tested for fluid sensitivity.

Extended Contact	Exposure	Test Condition	Code
100 Low Lead Aviation Fuel (ASTM D910)	90 days min. @ 70°F±10°F	70°F	FS11RT
	90 days min. @ 70°F±10°F	180°F	FS11ET
ASTM D1655 Jet A Fuel (other jet fuel may be used but its type must be reported)	90 days min. @ 70°F±10°F	70°F	FS12RT
	90 days min. @ 70°F±10°F	180°F	FS12ET
MIL-PRF-5606 Hydraulic Oil	90 days min. @ 70°F±10°F	70°F	FS13RT
	90 days min. @ 70°F±10°F	180°F	FS13ET
MIL-PRF-83282 Hydraulic Oil	90 days min. @ 70°F±10°F	70°F	FS14RT
	90 days min. @ 70°F±10°F	180°F	FS14ET
MIL-PRF-7808 Engine Oil	90 days min. @ 70°F±10°F	70°F	FS15RT
	90 days min. @ 70°F±10°F	180°F	FS15ET
MIL-PRF-23699, Class STD Engine Oil	90 days min. @ 70°F±10°F	70°F	FS16RT
	90 days min. @ 70°F±10°F	180°F	FS16ET
Sea Water (ASTM D1141 or equiv.)	90 days min. @ 70°F±10°F	70°F	FS17RT
	90 days min. @ 70°F±10°F	180°F	FS17ET
Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	90 days min. @ 70°F±10°F	70°F	FS18RT
	90 days min. @ 70°F±10°F	180°F	FS18ET
50% Water with 50% Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	90 days min. @ 70°F±10°F	70°F	FS19RT
	90 days min. @ 70°F±10°F	180°F	FS19ET
Short Duration Contact	Exposure	Test Condition	Code
MEK washing fluid. ASTM D740	90 minutes min. @ 70°F±10°F	70°F	FS21RT
	90 minutes min. @ 70°F±10°F	180°F	FS21ET
Polypropylene Glycol Deicer (Type I) SAE AMS 1424	90 minutes min. @ 70°F±10°F	70°F	FS22RT
	90 minutes min. @ 70°F±10°F	180°F	FS22ET
Isopropyl Alcohol Deicing Agent (TT-I-735)	48±4 hours @70°F±10°F	70°F	FS23RT
	48±4 hours @70°F±10°F	180°F	FS23ET
Control Tests	Exposure	Test Condition	Code
Distilled Water	90 days min. at 70°F±10°F	70°F	FS31RT
	90 days min. at 70°F±10°F	180°F	FS31ET
Dry	Dry per section 6.1 NTP AM-P-001	70°F	FS32RT
	Dry per section 6.1 NTP AM-P-001	180°F	FS32ET
85% Relative Humidity	Per section 6.1 NTP AM-P-001	70°F	FS33RT
	Per section 6.1 NTP AM-P-001	180°F	FS33ET

# CERTIFIED ADDITIVE MANUFACTURING FOR AIRCRAFT INTERIORS

## Stratasys Process Guidance

To help customers with implementation, Stratasys furnishes process guidance. An equivalency toolkit is provided to establish quality and consistency standards for the production of equivalency test coupons. The only customer-supplied equipment necessary is a vacuum drying oven and a milligram scale. Three-day on-site technical support is also included for system setup validation prior to accomplishing equivalency testing.

A Process Control Document provides specific guidance on engineering, material and process control requirements, and limitations for producing test coupons for equivalency testing. It includes information for process setup and control, print file preparation, fabrication and inspection. It is a critical part of this solution to validate satisfactory operation of the system prior to the production of test coupons.

## HOW IT HELPS

The Aircraft Interior Certification Solution gives aerospace companies the tools and process for achieving certification of additively manufactured parts for aircraft installation using NCAMP-qualified ULTEM 9085 resin material. The product creates a clear process path for part certification and avoids the need for companies to create their own set of design allowables. Instead, they simply need to show equivalency to a much smaller test lot using the Aircraft Interiors Configuration Fortus 900mc.

The combination of the AICS product and ULTEM 9085 resin design allowables helps aerospace companies save significant time and financial resources, and accelerate the implementation of certified additively manufactured parts.

## HOW TO GET IT

The Aircraft Interiors Certification Solution includes the following elements and is available from Stratasys. Contact your local Stratasys sales representative or [contact Stratasys](#) for more information.

- Certified ULTEM 9085 resin
- Material and process documentation
- Aircraft Interiors Configuration Fortus 900mc
- Equivalency toolkit
- Process Control Document

The B-Basis allowables dataset will be available on the NCAMP website.

## FAQS

### 1. **Is the hardware and software certification configuration upgrade to the Fortus 900mc necessary?**

Yes, an Aircraft Interiors Configuration Fortus 900mc Production System is a required part of this product. This configuration produces consistent build results necessary to show equivalency to the ULTEM 9085 resin design allowables dataset. It also provides improved material characteristics over the original configuration. An important element of this configuration is the Process Control Document, which provides the procedures for validating proper system operation prior to equivalency testing.

### 2. **Will a new Fortus 900mc need to be purchased?**

Customers with existing Fortus 900mc Production Systems only require the Aircraft Interiors Configuration upgrade and do not need to purchase a new system. Those who don't own a Fortus 900mc and are interested in purchasing this solution will need to buy the Aircraft Interiors Configuration Fortus 900mc.

## CERTIFIED ADDITIVE MANUFACTURING FOR AIRCRAFT INTERIORS

### 3. **Once a Fortus 900mc is upgraded can I start producing parts?**

Before producing parts the printer must be calibrated and validated for proper installation and performance. As part of this product, Stratasys customer support engineering will help the customer with on-site support and the necessary equipment to ensure the printer is set up and operating precisely. From there, a customer needs to build test coupons to perform equivalency testing to the original dataset of design allowables for ULTEM 9085 resin. The test results are used to show equivalency of the machine's build results to airworthiness authorities.

### 4. **Are parts built on an Aircraft Interiors Configuration Fortus 900mc considered certified?**

Parts by themselves are not certified by the FAA/EASA. However, they are approved as part of the aircraft's overall certification. This solution provides the tools needed to demonstrate to regulatory authorities that parts made with ULTEM 9085 resin material meet the design allowables developed by the NCAMP-approved test process.

### 5. **Is Stratasys on-site support necessary every time the Fortus 900mc requires qualification?**

No. The procedures to perform printer qualification are included with this solution and can be performed by the customer. Stratasys offers process guidance and support tooling as a service to customers as they need it. It should also be noted that this solution is site-specific, meaning that if a customer wishes to upgrade other existing Fortus 900mc Printers, purchase of the full product is not necessary, since the equivalency toolkit and documentation will have already been purchased. All that would be necessary in this scenario is the purchase of the ULTEM 9085 license, certified material and a new model material tip.

### 6. **What is the difference between Certified ULTEM 9085 and regular ULTEM 9085?**

Standard ULTEM 9085 filament canisters include a Certificate of Conformance that documents the material has been manufactured to established specifications. Certified ULTEM 9085 filament is produced in smaller batches, receives more frequent testing and is accompanied by additional documentation. Resin lot changes require complete cleaning of extrusion equipment to provide absolute lot identification and eliminate the possibility of cross-contamination between material lots.

### 7. **If parts and materials aren't certified by the FAA/EASA, why is the material used in this product called "Certified" ULTEM 9085?**

Stratasys uses the designation of "Certified" ULTEM 9085 to distinguish it from standard ULTEM 9085. It identifies that the quality management system governing the creation of the material, using a controlled specification and process, has been audited and approved by the FAA. Also, as explained in the previous question, Certified ULTEM 9085 undergoes more frequent testing and is accompanied by more documentation for full traceability, compared with the standard material.

### 8. **How were the aviation regulatory authorities such as the FAA involved in the development of this solution?**

The FAA provided oversight to the NCAMP process that established the design allowables for ULTEM 9085. Their supervision ensured that the testing and statistical analysis programs were sufficiently rigorous to develop the material properties and the equivalency process. Additionally, the FAA and NIAR provided guidance to Stratasys on development of the Process Specification to facilitate a successful process audit for equivalency testing.

### 9. **How/where can the design allowables for ULTEM 9085 resin material be accessed?**

They are published in the NCAMP library, accessible at the NCAMP website ([www.niar.wichita.edu/coe/ncamp.asp](http://www.niar.wichita.edu/coe/ncamp.asp)). Companies that want to access this information should first register with NCAMP.

### 10. **How are variations in part design accounted for?**

Basic material properties do not address the infinite variations of build strategies, design shapes and features. Each part would need to be evaluated during the certification process for items like environment, loading and criticality. Some companies develop a design handbook that provides guidance on standard design features and techniques. This is common practice for metallics and composites and will be similar with additively manufactured parts made with ULTEM 9085.



## CONTACT

For questions about the information contained in this document,  
contact Stratasys at [www.stratasys.com/contact-us/contact-stratasys](http://www.stratasys.com/contact-us/contact-stratasys).

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