NASA/TM-2015-218781/Volume II/Part 1 NESC-RP-12-00783





# Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

Appendices

Steven J. Gentz/NESC Langley Research Center, Hampton, Virginia

David O. Ordway, David S. Parsons, Craig M. Garrison, C. Steven Rodgers, and Brian W. Collins Marshall Space Flight Center, Huntsville, Alabama Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

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Mr. Lee Allen/MSFC for supporting Ken Johnson in statistically analyzing the post-processed data

Ms. Barbara Breithaupt/MSFC for post-processing the pseudo-velocity data.

Mr. Justin Jackson/MSFC for providing his expertise in composite test panel fabrication.

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### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

## **Volume II: Appendices**

# Part 1

April 16, 2015

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# Appendix A. Composite Test Panel Fabrication

### A1 Drawings

The following figures (Figure A1 through Figure A13) illustrate the Engineering drawings created to fabricate the pyroshock characterization of composite test panels and test support hardware.

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Figure A1. Al Pathfinder Panel

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Figure A2. IM7/R913 Composite Pathfinder Panel

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Figure A3. Al Linear Shaped Charge Plate

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Figure A4. LSC Backing Plate

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Figure A5. LSC Shim, 10 gpf

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Figure A6. LSC Shim, 22 gpf

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Figure A7. Monolithic Composite Test Panel, Tests 1-5

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Figure A8. Monolithic Composite Test Panel, Tests 6 – 10

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Figure A9. Sandwich Composite Test Panel, Group II

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Figure A10. Sandwich Composite Test Panel, Group III

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Figure A11. Composite LSC Test Plate

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Figure A12. Melamine Acoustic Barrier Foam

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Figure A13. LSC Splice Plate Drawing, 22 gpf LSC



## A2 Composite Panel Materials

### A2.1 Pathfinder Composite Panels

A series of five pathfinder tests, which were not included in the baseline T12-00783 task assessment plan (see Table 7.0-1). The objective for performing these tests was to validate the physical test setup and the DAS prior to embarking on the baseline tests. The first two tests utilized 5052 Al alloy plate with a thickness of 0.187 inches. The material properties for the IM7/R913 are shown in Figure A14.



### **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**



HexPly<sup>®</sup> 913

257°F (125°C) Curing Epoxy Matrix

Product Data

#### Description

HexPly<sup>®</sup> 913 is a proven modified epoxy matrix with a low temperature cure cycle which exhibits outstanding environmental resistance, whilst retaining good hot/vet mechanical performance. This versable matrix system can be processed using a wide range of techniques according to the application and is capable of co-cure with epoxy film adhesives.

#### **Benefits and Features**

- Exceptional environmental resistance
- . Controlled minimum viscosity giving easy processing
- Capable of being processed by various techniques.
- Good tack and drape characteristics
- . Long shelf life and out life at room temperature
- Compatible with Redux 312 adhesive film

#### Applications

HexPly<sup>®</sup> 913 is a highly successful matrix used extensively in the aerospace industry for primary aircraft structures and hetcopter blades. In addition 913 prepregs are used in various industrial and recreational products, which include medical equipment and bloss.

#### **Neat Resin Properties**

Property, Units US (SI)	Value	Test Method
Specific Gravity	1.02	ASTM D792
Tg, "F ("C)	314 (157)	DMA
Gel Time at 250F, mins	11.5	BSS7276
Density, Ibs/in <sup>3</sup> (g/cc)	0.0444 (1.23)	ASTM D792
G1C, in-Ibs/in <sup>2</sup>	6.10	ASTM D6671

Rheology Gel Time Viscosity poi Gei Time (minanes) 13000 39-1000: 20 100 100 ŵ 116. 140 65 90 100 110 120 130 140 Temperature "C Temperature \*C





Page #:



Product Data

#### Availability

Available	on a wide	variety of products:	
		10.00	

Form	Hexcel Designation	Fiber	Fiber Areal Wt. g/m <sup>2</sup>	Weave	Count Warp x Fill	Widths Available, In (cm)	Resin Content, %
Glass	120GL/R913 120GL/F913S	EDC 450 - 1/2	105	4H Satin	60 x 58	39 (96.5)	35 45
Fabric	7781GL/R913 7781GL/F913S	ECDE 75 - 1/0	300	8H Satin	67 x 64	39 (96.5)	35 39-40
Glass Tape	S2GL/R913	S2GL	111, 222, 284, 295, 2556	Tape: UD; ±45°, ±60° X-ply	n/a	16, 24, 36, 40, 48, 48.5 (41-123)	32.5 - 33
	AGP193/R913	AS4 GP 3K	193	Plain	11.5 x 11.5	60 (152)	37
Ā	AGP195CSW/ R913	AS4 GP 3K	195	4H Satin	11.5 x 11.5	60 (152)	38
Carbon	XAGP195/ R913	AS4 GP 3K	195	±45° 4H Satin	11.5 x 11.5	50 (127)	36
1 capito	XSGP196/ R913	IM7 GP 6K	196	±45° Plain	11 x 11	50 (127)	37
	W3X 286/ R913S	3K 33MSI	197	4H Satin	12 x 12	24 (61)	36
	AS4GP 12K/ R913	AS4GP 12K	272, 195	Таре	n/a	12, 48 (30.5-122)	34 - 35
Carbon Tape	IM2CGS 12K/ R913	IM2CGS- 12K	110, 140	Таре	n/a	12, 24 (30.5, 61)	31 - 38
	IM7G 12K/R913	IM7G 12K	148, 296	Tape, ±45° X-ply	n/a	12, 24, 36, 48 (30.5-122)	33
	IM8-GS 12K/ R913	IM9-GS 12K	70	Таре	n/a	24 (61)	38





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**Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading** 



Product Data

#### **Physical & Mechanical Properties**

Form:			Carbon	Fabric	Carbon Tape	
Category	Property	Parameter, Units US (SI)	AGP195CSW/ R913;38%; 195AW	XSGP196/ R913LM;37; 196AW	IMI7G/R913 ; 33%; 148AW	AS4GP 12K/R913; 35%; 272AW
		Resin Content (dry), %	30	37	33	35
	Prepreg:	Area Weight, g/m <sup>2</sup>	195	196	148	272
Physical	10 26 2	Volatile Content, %	< 0.5	< 0.4		< 0.2
Properties:		Cured Thickness per ply, inch (cm)	0.0070 (0.0178)	0.0084 (0.0214)	0.0056 (0.0142)	0.0101 (0.0257)
	Laminate:	Fiber Volume, %	62	199		60
	1	Density, g/cc	1.58	1242		1.61
	0' Tensile	Strength, ksi (MPa)	141 (970)	1997 - J	216 (1490)	331 (2280)
		Modulus, Msi (GPa)	10.1 (69.8)		12.2 (83.9)	19.5 (134)
		Strain,%	1.40	( <b>1</b> )	1.68	1.51
	90° Tensile	Strength, ksi (MPa)	145 (998)	152 (1048)	8	, ii
		Modulus, Msi (GPa)	10.3 (71.0)	10.9 (75.5)	12	i.
		Strain, %	1.38	1.34		
Mechanical	0*	Strength, ksi (MPa)	121 (832)	3979	81	224 (1540)
Properties:	Compression	Modulus, Msi (GPa)	9.5 (65.2)	1.1	5 <b>1</b>	17.9 (123)
	90*	Strength, ksi (MPa)	116 (799)	898	12	9.t
	Compression	Modulus, Msi (GPa)	9.7 (66.5)	(a)	34	- 54
	0' Short Beam Shear	Strength, ksi (MPa)	10.6 (73.3)	10.4 (71.8)	- 12	15.3 (105)
	a som onder	Strength, ksi (MPa)	-	131 (902)		
	0" Flexure	Modulus, Msi (GPa)		10.2 (70.2)	8.0	10

'Dry/Room Temperature Average Values





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**Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading** 

HexPly<sup>®</sup> 913

Product Data

	Form	1.)	Glass	Fabric	Glass Tape
Category	Property	Parameter, Units US (SI)	120GL/R913; 37%;105AW	7781GL/R913; 37%;300AW	S2GL/R913;33%; 280AW
		Resin Content (dry), %	37	37	33
Physical Properties:	Prepreg:	Area Weight, g/m <sup>2</sup>	105	300	290
rioperaco.	Laminate:	Density, g/cc	1.83	1.83	1.80
	0° Tensile 0°	Strength, ksi (MPa)	70.9 (489)	65.3 (450)	203 (1400)
9		Modulus, Msi (GPa)	3.1 (21.0)	3.2 (22.0)	6.4 (44.0)
anora anta		Strength, ksi (MPa)	85.3 (568)	66.7 (460)	160 (1100)
Mechanical	Compression	Modulus, Msi (GPa)		4.1 (28.0)	6.7 (46.0)
Properties:	0° Short Beam Shear	Strength, ksi (MPa)	10.7 (74.0)	9.4 (65.0)	11.9 (82)
	01.0	Strength, ksi (MPa)	104 (714)	88.5 (610)	11 82
	0" Flexure	Modulus, Msi (GPa)		3.3 (23.0)	

\*Dry/Room Temperature Average Values

#### Cure Cycle

Recommended Cure:

60 minutes at 257ºF (125°C) and 102 psi (700kPa) pressure. Heat up rate 3.6ºF (2°C) to 14.4ºF (8°C) per minute.

Alternative Cures:	
Temperature "F ("C)	Time (Min)
284 °F (140 °C)	40
302*F (150*C)	20
320% (160°C)	10

Components up to 0.118 inches (3 mm) thick can be cured without a dwell in the schedule provided that the heat-up rate is not more than 9°F (5°C)/minute. For thicker parts a dwell period is necessary in the heat-up to avoid the occurrence of a resin exotherm, but the dwell period will depend on the mass and type of tool. The standard dwell period is 30 minutes at 195°F during heat-up.



HEXC



HexPlγ <sup>®</sup> 913	Product Data
	HexPlγ <sup>®</sup> 913

#### Storage

Out Life 30 days @ 73\*F (23\*C) Guaranteed Shelf Life: 12 months @ 0%F (-18%C)

#### Storage Conditions

HexPly® 913 prepregs should be stored as received in a cool dry place or in a refrigerator. After removal from refrigerator storage, prepreg should be allowed to reach room temperature before opening the polythene bag, thus preventing condensation. (A full creel in its packaging can take up to 48 hours).

#### Precautions for Use

The usual precautions when handling uncured synthetic resins and fine fibrous materials should be observed, and a Safety Data Sheet is available for this product. The use of dean disposable inert gloves provides protection for the operator and avoids contamination of material and components.

#### Shipping

Prepreg is generally shipped in a sealed polyethylene bag in refrigerated transportation or in containers with dry ice.

#### **Disposal of Scrap**

Disposal of this material should be in a secure landfill in accordance with state and federal regulations

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- Reinforced Fabrics
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- Engineered Core
- HexTOOL\* composite tooling material
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Figure A14. Hexcel IM7/R913 Material Properties



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# A2.2 Task Baseline Composite Panels

The IM7/TC350 composite material manufactured by TenCate Advanced Composites was chosen for fabrication of the task baseline composite test panels. The material is a 350°F toughened epoxy resin system for structural advanced composite applications, which include space structures. The composite is available in both tape and fabric prepreg formats. This material was chosen over the more commonly used IM7/977-3 composite material for aviation and aerospace applications primarily due to long lead time for procurement (29 weeks). The material properties of TC350 (shown in Figure A15) and 977-3 (provided herein for reference in Figure A16) are similar.



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# **TECHNICAL DATA**

# **MATENCATE**

### **TC350 Resin System**

#### PRODUCT TYPE

350°F (177°C) Cure Toughened Epoxy Resin System

#### TYPICAL APPLICATIONS

- Aircraft Structures
- Space Structures
- Radomes and Antennae
- · Reflectors

#### SHELF LIFE

Tack Life 21 days tack life at 77°F(25°C) Out Life 60 days out life 77°F (25°C)

Frozen Storage Life

12 months storage life at <0°F (-18°C)

Tack life is the time during which the prepreg retains enough tack, drape and handling for easy component lay-up

Out life is the maximum time allowed at room temperature before cure.

#### **PRODUCT DESCRIPTION**

TC350 is a toughened resin system for structural advanced composite applications. TC350 offers an excellent balance of toughness, mechanical property translation and hot/wet performance and is easily processed via autoclave or press ouring operations. TC350 develops a 397°F (203°C) Tg after a 350°F (177°C) cure, which coupled with low moisture absorption translates into excellent hot/wet performance. TC350 is available with virtually all fiber reinforcements in unidirectional tape, slit unidirectional tape, woven and non-woven prepreg formats.

#### **TC350 PRODUCT BENEFITS**

- Excellent Mechanical Property Translation
- High Toughness
- · Easy Processing
- · Excellent Tack Properties
- · Self-adhesive to Core
- · Good Surfacing Properties

#### TYPICAL NEAT RESIN PROPERTIES

Density	1 29 g/oc
Dry Tg (by DMA)	397°F (203°C) cured at 350°F (177°C)
Wet Tg (by DMA)	320"F (160°C) cured at 350°F (177°C)
	after saturation at 85% RH and 160°F (71°C)
Gel Time	10 - 12 minutes at 350°F (177°C)

#### LAMINATE DATA USED IM-7 12K. 150 gsm FAW.

Properties	Condition (RTD, ETD, ETW)	Method	Results		
Tensile Strength ()*	810	ASTM D 3039	382(ksi)	2634 (MPs)	
Tensile Modules (*	RTD	ASTM D 3039	23(Msi)	158.6 (GPa)	
Tensile Strength O <sup>o</sup>	ÉTW	ASTM D 3039	350 (kp)	2413 (MPs)	
Tensile Modulus (*	£TW	ASTM 0 3039	23.7 (Mai)	163 (GPa)	
Tensile Strength Of	CTO	ASTM D 3039	383 (ks)	2641 (MPs)	
Tensile Modulos (*	C10	ASTM D 3239	23.6 (Ma)	162.7 (GPs)	
Tensile Strength 90*	RTD	ASTM D 3039	12.5 (ks)	86 (MPa)	
Tensilo Modulus 90°	RTD	ASTM D 3039	1.4 (Ms)	9.7 (3Pa)	
Tensile Strength 90°	CTD	ASTM 0 3039	16.5 (kp)	113 (MPa)	
Tensile Modules 90*	CTO	ASTM D 3039	1.5 (Ms)	10.5 (GP#	
Concressive Strength 0*	RTO	ASTM D 6641	275(ks)	1896 (MPa)	
Compressive Modulus 0*	810	ASTM D 6641	21 (Mai)	144.8 (GPs)	
Congressive Strength @*	ETW	ASTM D 6641	195.8 (ksi)	1350 (MPa)	
Congressive Modulus 0°	ETW	ASTM D 6641	20.5 (Ma)	141.3 (GPs)	
Compressive Strength 0*	CTD	ASTM D 6641	325.6 (ksi)	2245 (MPa)	
Compressive Modulus 0*	CTD	ASTM D 6641	23.1 (Mai)	159.3 (GPa)	
Conpressive Strength 90*	RTD	ASTM 0 6841	42.6 (km)	294 (MPa)	
Compressive Modulus S0*	STD	ASTM D 6641	1.4 (Msi)	5.5 (SPa)	
Compressive Strength 90*	CTD	ASTM D 6641	59.5 (ku)	410 (MPa)	
Concreasive Modulus 90*	CID	ASTM 0 6641	17 (Msi	117.(GPa)	

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## **TECHNICAL DATA**

## **MATENCATE**

TENCATE ADVANCED COMPOSITES USA, INC.

TC350 LAMINATE DATA USED IM-7 12K. 150 gsm FAW. Contisos from page 1 Condition Mathod Results Properties **Resin System** (RTD, ETD, ETW) ASTMD 5766 Open Hole Tensile Strength RTD 61.9 [csi] 407 (MPs) Open Hole Tensile Strength ETW ASTMD 5768 410 MPa1 495 (ksi) **CTD** ASTMD 5768 58.9 [kg] 406 MPa Open Hole Tensile Strength Open Hole Comp. Strangth ATD ASTMD 6484 44.3 (ks) 305 (MPa) Open Hole Comp. Strength ETW ASTMD 6481 222 (MPa) 32.2 (kg) Filled Hole Tensile Strength RTD ASTMD 6742 62.8 (ka) 433 (MPa) Filled Hole Tenaile Strength ETW ASTMD 6742 64.2 [ksi] 43 MPal AS7MD 6742 Filled Hole Tensile Strength **CTD** 60.4 [cg] 416 MPal Filled Hole Comp Strength ATD ASTMD 6742 61.2 [ka] 422 (MPa) Filled Hole Comp. Strength ETW ASTIMD 6742 51.7 (xa) 356 (MPs) CAI @ 1500 in-lb RTD ASTM D 7126/7137 37.5 (ka) 259 (MPa) In Plane Shear Str. 94/450 RTD A\$TMD 3518 15.3 (cs) 105 (MPs) In Plane Shear Med. (4/45) ASTMD 3518 0.72 (Ma) HTD. 50(2%) In Plane Shear Str. (+/-45) CTD ASTMD 3518 19.9 (kp) 137 (MPa) In Plane Shear Mod. (4/45) CTD ASTMD 3518 0.64 (Msi) 5.8 (GPa) BTD. ASTMD 5961 133.1.001 918 (MPE) Single Shear Bearing Str. Single Shear Bearing Str ETW ASTMD 5961 997 (ksi) 687.4 (MPa) ASTMD 2344 ILSS OF BTD 17.6 (km) 121 (MPs) ILSS 0° ETW ASTMD 2344 57 (MPs) 83(ks) ILSS 0\* CTD ASTMD 2344 22.2 (ks) 153 (MPa) ILSS ØVEKD OP RTD ASTMD 2344 17.5 [ks] 120.7 (MPa) - Autocisus core at 50 - 100 pci, Normalized to 60%. Wat Conditioning performed at 180°F171°CV665% RH until complete saturation. Floid exposures for USS testing were performed as an immersion soak for 90 days at 70% (21°C). ETW is 200% (121\*C); CTD is -65% [-54\*C]. TC350 TOUGHENED EPOXY RESIN SYSTEM: Cure cycle 4007 Hold at 350°F for 120 minutes minimum. (temperature based on lagging thermocouple) · Apply 25 inches Hg vacuum minimum 100 \* tol down at · Apply > 40 psi Heat up at pressure to autoclave. 25.57F.mi 200% Below 160°F, release pressure and remove 1007 (temperature based on lagging themacouple) TIME Page 2 of 4 10360\_DS\_091511



## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

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## **TECHNICAL DATA**

## **M TENCATE**

TENCATE ADVANCED COMPOSITES USA, INC.

X ILIIGAIL	
TC350	EPOXY PREPREG, ADHESIVE AND RESIN GUIDELINES AND HANDLING PROCEDURES
Resin System	The following guidelines are provided to our customer to assure that all customers are aware of the procedures to attain the best possible results from TerCate Advanced Composites (TCAC) Epoxy products. These resin systems will provide sound composite hardware and structures if some simple procedures are followed.
	Keep in mind that these procedures are good practice for all composite prepreg and adhesive mate- rials and should be used whenever possible.
	FREEZER STORAGE
	Epoxy resin materials have good shelf life at room temperature: however the life and performance of the material is best preserved with the following basic guidelines. Refer to the shelf life includ- ed in the product certificates. The epoxy material should be sealed in an aritight bag and kept frozen below 10°F [-12°C] when not being used for longest life and most consistent performance. A good safety measure is to have a bag of desiccant (Silica Moisture Absorber) in the core of the prepred roll just in case a pin-hole in the bag or other problem occurs.
	MOISTURE ABSORPTION AND SENSITIVITY
	While very resistant to moisture absorption after oure, epoxies can be adversely affected by moisture uptake prior to oure. For this reason, all materials must be "Thoroughly Thaved" to noom temperature prior to opening the sealed bag to avoid condensation on the material. Also, it is good practice to keep prepred and in process hardware in a sealed bag or vacuum bag if to be exposed to atmosphere for long periods of time.
	HANDLING OF MATERIALS
	When handling any prepreg materials, one should always be wearing clean, powder-free latex gloves. This will assure that no hand oils are transferred to the prepreg and/or composite during processing. The presence of oils in the part could lead to problems in both mechanical and electrica performance of the part. This also guards against any dermatitis that could occur with certain users
	NON-METALLIC HONEYCOMB AND FOAM CORE USE When using Non-Metallic honeycomb and foam core materials for sandwich structures, the mate- rials should always be dried in an oven prior to layup to drive off any moisture that may be in the core. The material should then be cooled in the presence of a desiccant, to avoid any moisture uptake. Following this procedure it is always a good idea to use the material as soon as possible to avoid re-hydration.
	Recommended Core Dry Time/Temp: 250°F (121°C) for 3-4 Hours
	SELF ADHESIVE PRODERTIES AND FILM ADHESIVE USE
	TCAC epoxy resins have been formulated to have good self-adhesive properties to core materi- als. However, this should not be taken as a green light to eliminate a film adhesive from a cored, structural piece of hardware. This option has been given by TCAC for customers who are looking for the best electrical properties available by not using a film adhesive. TCAC recommends that the structural integrity be verified your specification prior to end item usage and takes no responsibility otherwise
	If this option is exercised, the following modified cure cycle has been found to work well.
	<ol> <li>Ramp the part to 150°F – 160°F (66°C – 71°C) (Keep Pressure &lt;15 Psi)</li> </ol>
	<ol><li>Dwell for approximately 1 hour</li></ol>
	<ol> <li>Ramp the part to the dictated oure temperature for the resin and cure per the provided standard cure cycle</li> </ol>
	PROCESSING METHODOLOGY
Page 3 of 4 TC360_DS_091	Epoxy resins can be processed using an Autoclave, Press, Pressclave, or Oven Cure/Vacuum Bag For any application where the optimum properties are needed, TCAC recommends the use of an autoclaus



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Figure A15. TenCate IM7/TC350 Material Properties



Title:

## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading





CYCOM<sup>®</sup> 977-3 **Epoxy Resin** 

Description

Cycom 977-3 is a 350°F (177°C) curing resin. It is a toughened epoxy resin with 350°F (177°C) dry and 270°F (132°C) wet service capability.

Cycom 977-3 is formulated for autoclave or press molding and can be cured at 350°F (177°C) for six hours.

Unidirectional tape and woven fabric impregnated with Cycom 977-3 will retain tack for 21 days at 72°F (22°C). It has a longer mechanical out life suitable for fabrication of large structures.

#### Features and Benefits

- 350°F (177°C) cure
- Available on fabric and tape
- 350°F (177°C) dry service temperature
- 270°F (132°C) wet service temperature
- Laminate and sandwich panel usage
- · Autoclave or press mold processing
- Toughened epoxy using Cytec Engineered Materials' proprietary "co-continuous" morphology
- Impact resistant
- Shelf Life
  - 1 year at 0°F (-18°C )
  - 21 days at 72°F (22°C)

#### Applications

- Aircraft primary and secondary structure
- · Places where impact resistance is critical
- Places where hot wet performance is crucial

For more information contact: Cytec Engineered Materials Technical Service 4300 Jackson Street Greenville, TX 75402 903-457-8500

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CYCOM 977-3 Epoxy Resin (Continued)

#### **Typical Resin Properties**

The following figure is a typical viscosity curve for a ramp rate of 2°C/min.



Cured Resin Density = 1.29 g/cc

	RT	250°F / Wet 2 (121°C/Wet)
Compression Yield		
Strength (ksi)	$27 \pm 0.3$	
Strength (MPa)	186 ± 2.1	
Flexural	15470 V.C	8383-5658
Strength (ksi)	21 ± 4	$10 \pm 0.4$
Modulus (Msi)	$0.55 \pm 0.01$	$0.35 \pm 0.3$
Strength (MPa)	$144 \pm 30$	70 ± 3
Modulus (GPa)	3.8 ± 0.07	2.4 ± 2.1
K16' (MPa m1/2)	$0.9 \pm 0.08$	
G1c <sup>2</sup> (J/m <sup>2</sup> )	217 ± 24	
RDS DMA Tg (°C) 1/		
G'		178
G"		189
Tan Delta		190
Notes:		1.000
1/ tested at 5°C/min		
2/ Cured at 355°F (180°C) for 6	hours	
3/ Wet = 7 day water immersion	at 160°F (71°C)	
4/ Flexural testing preformed us	ing a 3 point loading fixture a	t a 16:1 S/D ratio
5/ Ktc and Gtc tested using 3 pc	int bending mode	

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#### CYCOM 977-3 Epoxy Resin (Continued)

#### Typical Prepreg Properties

#### 5 Harness Satin (5HS) Fabric

#### Standard Modulus Carbon Fiber (33 Msi / 228 GPa)

Typical Cytec Engineered Materials Product Code: Cycom 977-3/5HS AS4 6K;

Mechanical Properties	-65°F (-54°C)	RT	250°F (121°C)
0° Tensile Properties	0.0000000000		
Strength, ksi		$126 \pm 24$	
Modulus, Msi	$9.8 \pm 0.6$		
Strength, MPa	869±165		
Modulus, GPa		68±4	
0° Interlaminar Shear Properties			
Strength, ksi		13 ± 2	
Strength, MPa		90 ± 14	

#### **Unidirectional Tape**

Intermediate Modulus Carbon Fiber (40 Msi / 276 GPa)

Typical Cytec Engineered Materials Product Code: Cycom 977-3/IM7 12K

Mechanical Properties	-65°F (-54°C)	RT	250°F Wet (71°C)
0° Tensile Properties	8e - 99		26 I-
Strength, ksi		364	
Modulus, Msi		23.5	
Failure Strain (%)		1.46	
Strength, MPa		2510	
Modulus, GPa		162	
0° Compression Properties			0.0032010
Strength, ksi		244	195
Modulus, Msi		22.3	21.2
Strength, MPa		1682	1344
Modulus, GPa		154	146
0° Flexural Properties			
Strength, ksi		256	162
Modulus, Msi		21.7	21.2
Strength, MPa		1765	1117
Modulus, GPa		150	146
0° Interlaminar Shear Properties		0.000000	1101004
Strength, ksi		18.5	11.4
Strength, MPa			
Compression After Impact (ksi) 2/3/		28	
<u>Notes:</u> 1/ Wet = 1 week immersion in 160°F water 2/ 25/50/25 Orientation and			
3/ 270 in lb impact levels			



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CYCOM 977-3 Epoxy Resin (Continued)

#### Preparation for Laminate Curing

Treat surfaces that lay-up will touch with a release agent. As each ply of material is positioned, work out any wrinkles or entrapped air with a paddle or roller before removing the backing. Take care not to distort the material during lay up. Insert a thermocouple into the lay-up near the center ply of the thickest edge section, outside the net trim line.

To eliminate porosity, keep the resin under pressure during cure with the use of compressible dam. Nonpermeable fluorocarbon coated fabric should be placed over lay-up to protect the bag system in vacuum or autoclave cures.

Install a vacuum bag by standard techniques. Insert at least two vacuum ports through the bag, connecting one to a vacuum source and the other, at a point furthest away from the source, to a calibrated vacuum gage. Position part in oven or autoclave and draw vacuum to check for bag or system leaks. The following figure shows the recommended lay-up for CYCOM<sup>®</sup> 977-3 materials.



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Cycom 977-3 Recommended Lay-up

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#### CYCOM 977-3 Epoxy Resin (Continued)

#### **Recommended Cure Cycles**

The following cure cycle is recommended for molding CYCOM<sup>@</sup> 977-3 materials. Cure cycles should be tailored based on application.



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#### CYCOM 977-3 Epoxy Resin (Continued)

#### Product Safety

Materials Safety Data Sheets (MSDS) can be obtained from Cytec Engineered Materials by calling 903-457-8500.

#### Product Handling

The wearing of clean, impervious gloves is recommended when working with prepreg materials. See MSDS for more information.

#### Shipping

Prepreg is typically shipped as rolls in sealed polyethylene bags in cardboard containers packed with dry ice or by refrigerated carrier.

#### Disposal of Scrap Material

Disposal of material should be in accordance with federal regulations as well as local and stat regulations that may vary by location.

#### Warning

The data listed has been obtained from carefully controlled samples considered to be representative of the product described. Because the properties of the product can be significantly affected by the fabrication and testing techniques employed, and since Cytec Engineered Materials does not control the conditions under which its products are testing and used, Cytec Engineered Materials cannot guarantee that the properties listed will be obtained with other processes and equipment.

This is a technical data sheet, not a specification. The suggestions and data in this bulletin are based on information we believe to be reliable. They are offered in good faith, but without guarantee, as conditions and methods of use of products are beyond our control. We recommend that the prospective user determine the suitability of cur materials and suggestions before adopting them on a commercial scale. Suggestions for uses of our products should not be understood as recommendations that they be used in violation of any patents.

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#### Figure A16. Cycom IM7/977-3 Material Properties



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The Group I monolithic composite panels were fabricated using both tape ply and fabric ply in thicknesses of 0.20 inches and 0.30 inches. Depending upon the type of ply used (tape or fabric) and the desired panel thickness determines the number of plies required for composite layup. As a rule of thumb, the typical thickness for the tape ply is approximately 0.0055 inches and for the fabric ply, the typical thickness is approximately 0.011 inches. For the 0.20-inch-thick tape ply panel 38 plies were used and 54 tape plies were used for the 0.30-inch-thick tape ply panel. For the 0.20-inch-thick fabric ply panel 18 plies of fabric ply were used and for 0.30-inch-thick fabric ply panel 27 fabric plies were used. For the monolithic panels the ply layup was either unidirectional (0° (longitudinal with regard to the panel length)) or symmetrically quasi-isotropic  $(45^{\circ}/-45^{\circ}/0^{\circ}/0^{\circ}/45^{\circ}/-45^{\circ}/90^{\circ}/90^{\circ})n.$ 

For test Groups II and III, composite sandwich fill panels were fabricated. Two fill materials were chosen for the sandwich panels, which are typically used for aerospace applications; Al honevcomb and ROHACELL® foam. The fill thickness was held constant at 1.000 inch, regardless of the fill type. Eight-ply (either fabric or tape ply) IM7/TC350 composite face sheets were fabricated and bonded to both sides of the fill material with Cytec FM300 structural adhesive (reference Figure A17 for the FM300 adhesive material properties) and Scotch-Weld AF555M structural film adhesive (reference Figure A18 for the AF555M film adhesive properties) to make up the sandwich panels.



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## CYTEC

TECHNICAL DATA SHEET

AEROSPACE MATERIALS

## FM<sup>®</sup> 300 Epoxy Film Adhesive

#### DESCRIPTION

FM® 300 is a modified epoxy film adhesive available with three different moisture-resistant polyester carriers. It is designed for bonding metal-to-metal and sandwich composite structures. To achieve ultimate environmental resistance in bonding aluminum details, use pre-cured BR® 127 primer with FM 300 film adhesive.

Extensively used as a surface finished ply on composites material outside layers, FM 300 film adhesive has unique properties which drastically reduce, and in some cases virtually eliminate, time-consuming sanding and filling operations.

FM 300 film adhesive has high elongation and toughness with high ultimate shear strength. This makes it particularly suitable for redistributing the high shear stress concentrations of graphite epoxy- to-metal bonds, and allows it to accommodate the low interlaminar shear strength of the composite. It is particularly good in fatigue resistance in these joints. In properly designed and processed joints, the tight-knit tricot carrier provides a degree of electrical isolation between metal and graphite composites to reduce galvanic corrosion.

#### FEATURES & BENEFITS

- · Superior metal-to-metal peel strength, composite-to-composite bonding and composite-to-metal joints
- · Extensively used as surfacing ply for composite materials
- Service temperature from -67°F to 300°F (-55°C to 150°C)
- · Excellent moisture and corrosion resistance in high humidity environments with no significant reduction in mechanical properties
- · Allows x-ray inspection of assemblies due to natural opacity of adhesive formulations
- · Available in a wide range of film thicknesses tailored to specific applications
- · Industry wide acceptance

#### SUGGESTED APPLICATIONS

- Metal-to-metal bonding
- · Composite-to-composite bonding
- · Composite-to-metal bonding
- Composite surfacing

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#### CHARACTERISTICS

Table 1 | Product Description for FM 300 Adhesive Films

Product Number	Weight, psf (gsm)'	Nominal Thickness, inches (mm)	Color	Carrier	Characteristics
FM 300 film adhesive	0.08 (390) 0.10 (490)	0.013 (0.32) 0.015 (0.38)	Blue Blue	Tight knit	Enhanced bondline thickness control. Good blend of structural and handling properties
FM 300K film adhesive	0.05 (244) 0.08 (390)	0.008 (0.20) 0.013 (0.32)	Green Green	Wide open knit	Highest overall performance
FM 300M film adhesive	0.03 (150) 0.08 (390)	0.005 (0.13) 0.013 (032)	Green Green	Random mat	Provides the best bondline and flow control. Reduces tendency to trap air during lay-up.
FM 300U film adhesive	0.03 (150) 0.055 (268)	0.005 (0.13) 0.008 (0.20)	Green Green	Unsupported film	Can be reticulated

\*Weight tolerance equals nominal weight ± 0.005 pd (± 25 gar)

#### Table 2 | Handling Properties of FM 300 Adhesive Films

Properties	Description
Volatiles	1.0% maximum
Outgassing properties (after complete cure)	0.92% TWL and 0.07% CVCM (NASA reference publication 1124, Rev. 8/87)
Recommended storage	Supported grades: store at or below 0°F (-18°C) Unsupported grades: store at 40°F (4.5°C)
Shelf life	Supported Grades: 12 months from date of shipment Unsupported Grades: 4 months from date of shipment
Shop life	10 days at 90°F (32°C) 30 days at 70°F (21°C)

#### Table 3 | Product Description: BR® 127 corrosion inhibiting primer

Properties	Description
Color	Yellow
Solids	10% ± 1% sprayable
Density	7.3 lbs/gal (875 g/liter)
Shop life	5 days at 90°F (32°C)
Shelf life	12 months from date of shipment at recommended storage
Recommended	Store at or below 0°F (-18°C)

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FM® 300 EPOXY FILM ADHESIVE

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#### PROPERTIES

Table 4 | Mechanical Properties<sup>1</sup>

Sample Description <sup>2</sup> Product Number	FM 300 0.08 psf (390 gsm)	FM 300K 0.05 psf (244 gsm)	FM 300K 0.08 psf (390 gsm)	FM 300M 0.03 psf (150 gsm)	FM300M 0.08 psf (390 gsm)
Tensile shear, psi (MPa)				1	
-67*F (-55*C)	5080 (35.0)	-	5460 (37.7)	-	4930 (34.0)
75°F (24°C)	5145 (35.5)	5340 (36.8)	5850 (40.3)	4325 (29.8)	5275 (36.4)
250*F (120*C)	3995 (27.6)	3575 (24.7)	4200 (28.9)	3360 (23.2)	4040 (27.9)
300°F (150°C)	2910 (20.0)	2965 (20.4)	3155 (21.8)	2310 (15.9)	2955 (20.4)
Floating roller peel, in-Ib/in (kN/m)					
-67*F (-55*C)	28 (4.9)	-	28 (4.9)	-	29 (5.1)
75"F (24"C)	29 (5.1)	23 (40)	28 (4.9)	26 (4.6)	29 (5.1)
250°F (120°C)	-	-	-	-	-
300°F (150°C)	25 (4.4)	-	26 (4.6)	27 (4.7)	26 (4.6)
Honeycomb sandwich peel, in-ib/3 in (Nm/m)		-		-	
-67"F (-55"C)	2	25 (37)	40 (58)	-	
75°F (24°C)	-	22 (32)	45 (66)	11 (16)	1
250°F (120°C)	-	-	-		
300"F (150"C)	-	22 (32)	28 (41)	-	-
Flatwise tensile, psi (MPa)					
-67*F (-55*C)	1350 (9.3)	-	1075 (7.4)	-	1600 (11.0)
75°F (24°C)	1095 (7.6)	-	1030 (7.1)	435 (3.0)	1390 (9.6)
250°F (120°C)	-	-	-	-	
300°F (150°C)	345 (2.4)	340 (2.3)	470 (3.2)	125 (0.86)	513 (3.5)

YM 300, FM 300K and FM 300M film adhesives with BR 127 primer. Typical average results.
\* Metal: Tensile shear 0.063 in. (1.63 mm) 2024-T3 dad, honeycomb skins 0.020 in. (0.51 mm) 2024-T3 dad, honeycomb 3/16 in. (4.76 mm) 0.002 (0.65 mm) NP5052, floeting roller peel 0.02540.063 2024-T3 dad

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#### FM® 300 EPOXY FILM ADHESIVE

#### Table 5 | Humidity and Fluid Exposure<sup>1</sup>

0.08 psf (390 gsm)	FM 300K 0.08 psf (390 gsm)	FM 300M 0.08 psf (390 gsm)
5185 (35.8)	6225 (42.9)	5535 (38.2)
5030 (34.7) 4915 (33.9) 5100 (35.2) 5155 (35.6)	6240 (43.0) 6275 (43.3) 6130 (42.3) 6095 (42.0)	5550 (38.3) 5250 (36.2) 5350 (36.9) 5125 (35.3)
4935 (34.0)	6350 (43.8)	4860 (33.5
	0.08 psr (390 gsm) 5185 (35.8) 5030 (34.7) 4915 (33.9) 5100 (35.2) 5155 (35.6) 4935 (34.0)	0.08 psf         0.08 psf         0.08 psf           (390 gsm)         (390 gsm)           5185 (35.8)         6225 (42.9)           5030 (34.7)         6240 (43.0)           4915 (33.9)         6275 (43.3)           5100 (35.2)         6130 (42.3)           5155 (35.6)         6095 (42.0)           4935 (34.0)         6350 (43.8)

Table 6 | Effect of Humidity Exposure on Film Prior to Bonding<sup>3</sup>

Property	Test Condition	Control (no exposure)	15 Day Exposure at 54% RH
	Tested at 75*F (24*C)	4800 (33.1)	4900 (33.8)
		4700 (32.4)	4800 (33.1)
Tensile shear, psi (MPa)	Test Condition         Control (no exposure (no exposure 4800 (33)           Tested at 75°F (24°C)         4800 (33)           Tested at 75°F (24°C)         4650 (32)           Tested at 300°F (150°C)         3400 (23)           Tested at 300°F (150°C)         3300 (22)           Tested at 75°F (24°C)         28 (4)           Tested at 75°F (24°C)         29 (5)           In.         Tested at 75°F (24°C)         75 (11)	4650 (32.1)	5200 (35.9)
		3400 (23.5)	2600 (17.9)
		3300 (22.8)	2900 (20.0)
Floating collectored like (cN/m)	Tested at 75*F (24*C)	28 (4.9)	28 (4.9)
ridating roller peet, lastin (krivin)		29 (5.1)	29 (5.1)
Honeycomb sandwich peel, In-Ib/3 in.	Tested at 75*F (24*C)	75 (110)	75 (110)
(Nm/m)		68 (100)	69 (100)

\* Sample: FM 300K film adhesive, 0.06 psf (390 gam) with BR 127 primer

Matul

 Tensile shear
 0.063 in. (1.63 mm) 2024-T3 dad

 Honeycomb skins
 0.020 in (0.51 mm) 2024-T3 dad

 Honeycomb
 3/16 in. (4.76 mm) 0.002 (0.65 mm) NP 5052

 Hosting roller peel
 0.0250.063 2024-T3 dad

Cure cycle: 60 minutes to 350°F (175°C) 60 minutes at 350°F (175°C) 40 psl (0.28 MPz)

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## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

FM® 300 EPOXY FILM ADHESIVE

#### Table 7 | 300°F (150°C) Heat Aging Studies

Hours exposure	Tensile shear psi (MPa) tested at 75°F (24°C)	Tensile shear psi (MPa) tested at 300°F (149°C)	Honeycomb sandwich peel in-lb/3 in (Nm/m) tasted at 75°F (24°C)	Flatwise tensile, psi (MPa) tested at 75°F (24°C)
Control	6070 (41.8)	2980 (20.6)	64 (94)	1380 (9.5)
1440	4460 (30.8)	3720 (25.6)	35 (52)	-
2880	4700 (32.4)	3400 (23.5)	41 (60)	960 (6.6)
4320	4300 (29.7)	3430 (23.7)	26 (39)	1000 (6.9)
5040	3910 (27.0)	3530 (24.4)	23 (34)	990 (6.8)
5760	3210 (22.1)	3450 (23.8)	20 (30)	950 (6.6)
7200	3580 (24.7)	3450 (23.8)	20 (30)	_
7920	3270 (22.6)	2960 (20.4)	17 (25)	780 (5.4)

Sample: FM 300K film adhesive, 0.06 psf (890 gsm) with 8R 127 primer

etal: Tensile sheer 0.063 in. (1.63 mm) 2024-T3 dad Honeycomb skins 0.020 in (0.51 mm) 2024-T3 dad Honeycomb 3/16 in. (4.76 mm) 0.002 (0.65 mm) NP 5052

Cure cycle: 60 minutes to 350°F (175°C) 60 minutes at 350°F (175°C) 40 ps (0.28 MPa)

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#### KGR Stress Strain Data

The heart of Cytec is new technology for structural adhesives is the KGR-1 extensioneter. This instrument provides the basic, definitive property of a structural adhesive – its shear stiffness. KGR-1 records the entire stress strain curve for the adhesive in environments reproducible in the laboratory.

This technology benefits both the designer and the adhesive formulator. The designer and stress analyst use this technology to predict the service performance of the adhesive bond, including strength, creep and fatigue in environments reproducible in the laboratory.

Until Cytec developed the KGR-1, test methods to obtain shear stiffness were either inaccurate or too costly to allow sufficient data for statistical confidence. A measure of the difficulty in obtaining this stiffness is that movements of one quarter of a micron (0.00001 inches) must be detected with clarity and reliability. KGR-1 does this over a temperature range of -67°F (-55°C) to 500°F (260°C) in hostile environments reproducible in the laboratory.

The economy of operation of KGR-1 makes stiffness data affordable to the designer. This economy allows statistical confidence necessary for practical analysis. In addition to stiffness, KGR-1 provides the shear stress strain relationship over the entire non-linear range up to and including ultimate failure.

It is established that fatigue life and residual static strength are dependent on strain at ultimate stress. The larger the strain, the longer the fatigue life and the higher the residual static strength (the strength after the joint has seen the required fatigue loads). This data defines limits for creep and fatigue conditions. It is possible to perform proper stress analysis of bonded eircraft primary structure. Accurate predictions are now possible for the bond performance over the life of the aircraft.

Apart from its value to the designer, KGR-1 technology is invaluable to the formulator of structural adhesives. Stress strain properties beyond the linear range define the adhesive's performance in fatigue and toughness.

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FM® 300 EPOXY FILM ADHESIVE

If you are interested in acquiring a KGR-1 exensometer for help in your own work, please contact a Cytec representative.



Table 6 | KGR-1 Stress Strain Data for FM 300K Adhesive Film, 0.06 psf (290 gsm) with BR\* 127 Primer [f = Shear Stress, psi (MPa). = Shear Strain, In/In. G = Shear Modulus, psi (Mpa)]

Test	Linear Limit (LL)		Knee (KN)		Ultimate Failure (UL)		
Temperature	f	Σ	G	f	Σ	f	Σ
75°F (24°C)	2050 (14.2)	0.0156	131,500 (907.5)	6100 (42.1)	0.0932	7210 (49.8)	0.5446
220"F (104"C)	916 (6.32)	0.0150	64,700 (446.2)	3000 (20.8)	0.0835	5190 (35.8)	1.2073
220"F (104"C)"	745 (5.14)	0.0273	27,500 (189.8)	1880 (13.0)	0.1047	3100 (21.4)	1.0744

<sup>1</sup> Postbond exposure to 100% RH at 140°F (60°C) until saturated

Figure 9 | Shear Stress vs. Shear Strain for FM 300K Film Adhesive in Various Environments KGR-1 Instrumentation



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#### **APPLICATION NOTES**

#### Preparation of Aluminum

A clean, dry, grease-free surface is required for optimum performance. A recommended procedure for cleaning aluminum skins prior to priming or bonding is the FPL cleaning method:

1. Vapor degrease, alkaline clean, rinse and check for water break

2. Prepare a sodium dichromate/sulfuric acid solution as follows:

a.	Mix the following ingredi	ents:	
	Sodium Dichromate	34 grams	FED-O-S-595A
	Water	700 ml	Deionized water recommended
	Sulfuric Acid	304 grams	FED-O-A-115, Class A, Grade 2

b. Add additional water to make one liter

This solution will dissolve 1.5 grams of 2024 clad aluminum per liter.

NOTE: Chromic acid is highly corrosive. All contact with skin and tissues must be prevented. Wear impervious apron, boots and gloves as well as splash-proof goggles and face shield when preparing and/or using chromic acid. If airborne concentration of chromic acid exceeds the 8-hr TWA established by OSHA, respirators approved by NIOSH must be worn.

Chromic acid solutions should be prepared and handled only in fume hoods or other adequately ventilated areas even when the TWA is not exceeded. Traces of chromyl chloride may occur in the vapors above heated chromic acid solutions prepared from chlorinated water.

- Immerse aluminum part in sodium dichromate/sulfuric acid solution at 155 ± 5°F (68 ± 3°C) for 10 minutes (clad aluminum) or 5 minutes (bare aluminum)
- 4. Spray rinse with water at or below 75°F (24°C)
- 5. Immerse in cold water
- 6. Repeat spray rinse checking for water break
- 7. Dry in a vented oven below 150°F (65°C)

In addition to the FPL etch cleaning method for aluminum, the phosphoric acid anodizing (PAA) surface treatment1 is now being used by a large number of aircraft manufacturers due to the improved surface bond durability provided by the PAA treatment.

#### **Primer Application**

Although not mandatory, BR 127 corrosion inhibiting primer is recommended for use with FM 300 adhesive in the bonding of aluminum details. BR 127 primer offers superior durability and resistance to hostile environments within the bond line and also may be used as a protective coating outside the bonded areas. Apply BR 127 as follows:

- 1. Allow BR 127 material to warm to room temperature prior to opening container
- 2. Thoroughly mix before application and agitate during application
- Spray or brush coat to a dry primer thickness of 0.0001 inch (0.0025 mm) nominal with a 0.0002 inch (0.0050 mm)
  maximum thickness
- 4. Air dry 30 minutes minimum prior to using
- 5. Oven dry 30 minutes at 250 ± 10\*F (120 ± 6\*C)

1 Boeing patent 4,085,012; April 18, 1978

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## **Composite Materials Subjected to Pyroshock Loading**

#### **Bonding Procedure**

Bond FM 300 film adhesive at pressures ranging from 15 - 100 psi (0.10 - 0.69 MPa) depending upon the application. For press, autoclave, pressure diaphragm or vacuum bag curing use the following cure cycle:

- 1. Heat up to 350°F (175°C) in 30 60 minutes
- 2. Hold at 350°F (175°C) for 60 minutes

#### Compatibility

The cure temperature, pressure and gel time of FM 300 film adhesive make it compatible for co-cure or simultaneous autoclave runs with FM® 61 and FM® 96 film adhesives as well as BR 127 primer.

#### PRODUCT HANDLING AND SAFETY

Cytec Industries recommends wearing clean, impervious gloves when working with epoxy resin systems to reduce skin contact and to avoid contamination of the product. Materials Safety Data Sheets (MSDS) and product labels are available upon request and can be obtained from any Cytec location supplying aerospace materials.

#### DISPOSAL OF SCRAP MATERIAL

Disposal of scrap material should be in accordance with local, state, and federal regulations.

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Figure A17. Cytec FM300 Adhesive Material Properties



## 3M Scotch-Weld<sup>™</sup> Structural Adhesive Film AF 555

Product Description	3M™ Scotch-Weld™ Structural Adhesive Film AF 555 is a thermosetting, modi epoxy adhesive □m. It was designed for bonding of composites in conjunction w honeycomb or in a monolithic structure. Scotch-Weld AF 555 Film can be co-cu co-bonded with composite prepregs, or used to bond cured composite.			
Key Features	DExcellent pre-bond humidity perfor	mance on composite	substrates.	
	□One-year out-time at ambient condi-	itions.		
	□Unsupported version available for r	eticulation.		
	□Film adhesive can be cured from 30	0°F (150°C) up to 35	5°F (180°C).	
	DExcellent shop handling characteris	tics (easy to use in sh	op).	
	DAvailable with light-weight conduct	tive screens for lightr	ing strike/composit	
	surfacing applications.	en de la compañía de	0	
Available Constructions		1	1	
CONST OCCURS.	Construction	Weight (± .005) Lb/ft <sup>2</sup>	Nominal Thickness (mils)	
	Scotch-Weld AF 555U Film	0.015	2.5	
	Scotch-Weld AF 555U Film	0.030	5.5	
	Scotch-Weld AF 555U Film	0.035	6.0	
	Scotch-Weld AF 555U Film	0.050	8.0	
	Scotch-Weld AF 555U Film	0.060	10.0	
	Scotch-Weld AF 555U Film	0.080	13.0	
	Scotch-Weld AF 555M Film	0.015	2.5	
	Scotch-Weld AF 555M Film	0.030	5.5	
	Scotch-Weld AF 555M Film	0.0325	5.75	
	Scotch-Weld AF 555M Film	0.035	6.0	
	Scotch-Weld AF 555M Film	0.050	8.0	
	Scotch-Weld AF 555M Film	0.060	10.0	
	Scotch-Weld AF 555M Film	0.080	13.0	
	Scotch-Weld AF 555K Film	0.050	8.0	
	Scotch-Weld AF 555K Film	0.080	13.0	
	Scotch-Weld AF 555K Film	0.100	16.0	

K = Knit Supporting Carrier L = Lightweight Non-Woven Supporting Carrier

Scotch-Weld AF 555 Clms are orange in both their uncured and fully cured form.

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Typical Cured Physical Properties Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

I. Torsion RDA

Test Equipment: Rheometric Dynamic Analyzer

3M<sup>™</sup> Scotch-Weld<sup>™</sup> Structural Adhesive AF 555 Film unsupported adhesive was cured under standard conditions. Specimen size: 33.848 (L) x 12.44 (W) x 1.94 mm (T).



II. Dry / Wet Glass Transition Temperature Cured Scotch-Weld AF 555 Film dry unconditioned vs. Scotch-Weld AF 555 Film aged in D1 water for 1000 hours at 80°C.

	Onset Temp F [C]	Tan Delta Peak F [C]
Scotch-Weld AF 555 Film unconditioned	304 [151]	338 [170]
Scotch-Weld AF 555 Film aged in DI water for 1000 h @ 80°C	279 [137]	325 [163]





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3M<sup>™</sup> Scotch-Weld<sup>™</sup> Structural Adhesive Film AF 555

Typical Cured Physical Properties (continued) Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

III. Metal to Metal - Overlap Shear

Overlap Shear Specimens: 1" wide, 1/2" overlap specimen, 0.063" thick, FPL etched and phosphoric acid anodized 2024-T3 bare aluminum. Primed with 3M™ Scotch-Weld™ Structural Adhesive Primer EW-5000.

Test Temperature °F (°C)	Scotch-Weld AF 555 Film U 0.030 Wt. PSI (MPa)	Scotch-Weld AF 555 Film M 0.050 Wt. PSI (MPa)	Scotch-Weld AF 555 Film K 0.080 Wt. PSI (MPa)
-67 (-55)	4776 (33)	4850 (33)	4770 (33)
75 (23)	5416 (37)	5634 (39)	5765 (40)
277 (136)	2606 (18)	3016 (21)	4355 (30)
350 (177)	1571 (11)	1526 (11)	2252 (16)

IV. Metal to Metal - Floating Roller Peel

Floating roller peel specimens: 1/2" wide, 0.063" back panel, 0.025" skin 2024-T3 bare aluminum, FPL etched and phosphoric acid anodized. Primed with 3M™ Scotch-Weld™ Structural Adhesive Primer EW-5000.

Test Temperature °F (°C)	Scotch-Weld AF 555 Film U 0.030 Wt. PIW (N/25mm)	Scotch-Weld AF 555 Film M 0.050 Wt. PIW (N/25mm)	Scotch-Weld AF 555 Film K 0.080 Wt. PIW (N/25mm)
-67 (-55)	22 (97)	25 (111)	20 (89)
75 (23)	38 (169)	37 (165)	31 (138)
180 (177)	39 (173)	39 (173)	29 (129)

V. Metal to Honeycomb - Flatwise Tensile

All properties were measured on 2" x 2" honeycomb sandwich bonds. Primer used 3M™ Scotch-Weld™ Structural Adhesive Primer EC-3917. Tested in accordance with MIL-A-25463B and ASTM C-297.

Test Temperature		0.06M Wt. Supported, Unreticulated	
°F	°C	PSI	(MPa)
75	(23)	1117	(7.3)
277	(136)	468	(3.24)



 
 Typical Cured
 Note: The following technical information and data is based on limited 3M testing Physical Properties

 conditions and should not be used for specification purposes.

 (continued)

#### VL High Temperature Durability Data - Metal to Metal Wide Area Overlap Shear

Bonds were made on FPL etched and phosphoric acid anodized 2024-3T bare aluminum and exposed at 350°F (177°C). Overlap shear values were obtained at 75°F (23°C) and at 350°F (177°C) as indicated below. Primer used 3M<sup>TM</sup> Scotch-Weld<sup>TM</sup> Structural Adhesive Primer EC-3917. Tested in accordance with 3M TM C-265 (Aluminum to Aluminum Blister Detection Test).

Hours of exposure at 350°F (177°C)	Scotch-Weld AF 555 Film 0.06M Wt. Supported PSI (MPa)		
	at 75°F (23°C)	at 350°F (177°C)	
0	3942 (27.2)	1981 (13.7)	
240	4206 (29.0)	2066 (14.2)	
864	4312 (29.7)	2115 (14.6)	
1440	4193 (28.9)	2121 (14.6)	

#### VII. High Temperature/Humidity Durability Data - Metal to Metal Wide Area Overlap Shear

3M<sup>™</sup> Scotch-Weld<sup>™</sup> Structural Adhesive Film AF 555 was exposed at the following temperature/humidity and loads for the number of days specified below before measuring creep. Bonds were made on FPL etched and phosphoric acid anodized 2024-T3 bare aluminum – using Scotch-Weld BC-3917 Primer and Scotch-Weld AF 555 Film 0.06M wt. supported. Specimens prepared in accordance with 3M TM C-265 (Aluminum to Aluminum Blister Detection Test).

Temp	erature	Humidity	Load	Measured Creep	Creep	Sustained Load
°F	(°C)	(RH%)	(PSI)	(years)	(mil) (mm)	(days)
140	(60)	100	2000	3	<0.5 (0.0127)	150
140	(60)	100	1500	3	<0.5 (0.0127)	150
140	(60)	100	1100	3	<0.5 (0.0127)	150
140	(60)	100	800	3	<0.5 (0.0127)	150
300	(149)		800	3	<0.5 (0.0127)	150
75	(23)	ambient	1600	3	<0.5 (0.0127)	150

#### VIII. Thick Adherend Shear

Scotch-Weld AF 555 Film tested on 1/2" thick FPL etched, Phosphoric Anodized 2024-T3 Aluminum primed with 3M<sup>7M</sup> Scotch-Weld<sup>7M</sup> Adhesive Primer EW-5000 AS. Full report available from 3M Technical Service upon request.

Test Temperature, °F (°C)	Ultimate Stress, psi (MPa)	Ultimate Strain, %	Shear Modulus, psi (MPa)
-65 (-54)	9660 (67)	0.309	0.171 (0.0012)
75 (24)	7610 (52)	0.556	0.063 (0.0004)
200 (93)	5220 (36)	0.935	0.041 (0.0003)
277 (136)	3790 (26)	1.344	0.011 (0.00008)



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> 3M<sup>™</sup> Scotch-Weld<sup>™</sup> Structural Adhesive Film AF 555

Typical Cured Note: The following technic Physical Properties conditions and should

Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

#### IX. Composite to Honeycomb - Short Beam Shear

All properties were measured on 3" X 6" specimens configured with three (3) plies of BMS8-256, Type IV, Class 2, Style 3K-70-PW co-cured at 350"F on each side of BMS8-124, Type I, Class 1, Grade 8.0 (.50 inch thick and transverse with 6" dimension) honeycomb core with one ply of  $3M^{TM}$  Scotch-Weld<sup>TM</sup> Structural Adhesive Film AF 555 at each core/skin interface. Beam shear was tested in a three point configuration with a 4.00 ± 0.05" span with the tool side up (in compression) to MIL-STD-401 guidelines.

Test Temperature	Construct	Ib <sub>r</sub>	kN
75°F (24°C)	Scotch-Weld AF 555M Film .030 psf	2360	10.5
75°F (24°C)	Scotch-Weld AF 555M Film .035 psf	2316	10.3
75°F (24°C)	Scotch-Weld AF 555M Film .050 psf	2202	9.79
75°F (24°C)	Scotch-Weld AF 555K Film .050 psf	2264	10.1
75°F (24°C)	Scotch-Weld AF 555K Film .080 psf	2485	11.1

#### X. Composite to Composite - Flatwise Tensile

All properties were measured on 2" X 2" specimens configured with three (3) plies of BMS8-256, Type IV, Class 2, Style 3K-70-PW co-cured at 350°F on each side of BMS8-124, Type I, Class 1, Grade 8.0 (.50 inch thick) honeycomb core with one ply of Scotch-Weld AF 555 Film at each core/skin interface. Flatwise Tension Test Blocks were subsequently bonded prior to testing and tested in accordance with MIL-STD-401.

	Test Temperature	Construct	PSI	MPa
5	-65°F (-55°C)	Scotch-Weld AF 555M Film .030 psf	1156	7.97
	75°F (24°C)	Scotch-Weld AF 555M Film .030 psf	1170	8.07
1	160 °F (71 °C)	Scotch-Weld AF 555M Film .030 psf	1000	6.89
5	-65°F (-55°C)	Scotch-Weld AF 555M Film .035 psf	1087	7.49
	75°F (24°C)	Scotch-Weld AF 555M Film .035 psf	1062	7.32
Ĩ.	160 °F (71 °C)	Scotch-Weld AF 555M Film .035 psf	949	6.54
2-	-65°F (-55°C)	Scotch-Weld AF 555K Film .050 psf	849	5.85
	75°F (24°C)	Scotch-Weld AF 555K Film .050 psf	1092	7.53
Ĩ.	160 °F (71 °C)	Scotch-Weld AF 555K Film .050 psf	1129	7.78
1	-65°F(-55°C)	Scotch-Weld AF 555M Film .080 psf	1174	8.09
	75°F (24°C)	Scotch-Weld AF 555M Film .080 psf	1266	8.73
1	160 °F (71 °C)	Scotch-Weld AF 555M Film .080 psf	1137	7.84



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#### 3M<sup>\*\*</sup> Scotch-Weld<sup>\*\*</sup> Structural Adhesive Film AF 555

**Typical Cured** 

**Physical Properties** 

Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

#### XI. Composite to Composite Overlap Shear

All properties were measured on 1" wide, 1/2" overlap specimen cut from epoxy/graphite fiber, ten ply unidirectional composite. Composite panels were cured using ten plies of carbon fiber prepreg, available as "Toray 3900-2/T800S", having an areal weight of 190 grams/meter<sup>2</sup> and a resin content of 35% (from Toray<sup>18</sup> Carbon Fibers America, Incorporated, Decatur, Alabama). Tested in accordance with ASTM D3165.

Test Temperature		3M <sup>TM</sup> Scotch-Weld <sup>TM</sup> Structural Adhesive Film AF 555 0.06M Wt.	
°F	°C	PSI	(MPa)
75	(23)	5224	(36.0)
277	(136)	2938	(20.3)

#### XII. Composite Double Cantilever Beam (DCB) Test Per BMS 8-276

Mechanical Test to determine strength after Glasochrom Pencil Markings BMS 8-276

Composite Material Spec Adhesive

Scotch-Weld\*\* AF 555 Film 0.05M Wt. Supported

N. 111150-	
andition	
onduon	

Test Co 75°F Width Crack Length G1c Area Energy in\*lbf in\*lbf/in^2 in^2 in in Lot # A 0.498 4.227 2.1071 9.466 4.490 Lot #B 0.497 3.856 1.9164 8.038 4.213 Lot # C 0.497 7.839 3.8959 19.182 4.924 Lot # D 0.500 5.074 2.87 14.972 5.901 Lot # E 0.498 6.384 3.1792 16.040 5.050 3.6440 18.035 Lot #F 0.497 7.332 4.949

#### XIII. Out Time: Room Temperature Exposure

Scotch-Weld AF 555 Film was exposed at 77F (23C) / ambient humidity for the number of months specified prior to bonding. Primer used was 3MTM Scotch-WeldTM Structural Adhesive Primer EW-5000. Overlap shear was tested in accordance with ASTM D1002. Floating Roller Peel was tested in accordance with ASTM D3167-97.

Overlap Shear Specimens: 1" wide, 1/2" overlap specimen, 0.063" thick, FPL etched and phosphoric acid anodized 2024-T3 bare aluminum. Primed with Scotch-Weld EW-5000 Primer.

Scotch-Weld AF 555U Film 0.030 wt., Overlap Shear vs. Out Time

Test Temperature	0 Month PSI (MPa)	6 Months PSI (MPa)	12 Months PSI (MPa)
75F (23C)	5416 (37)	5243 (36)	5005 (35)
277 F (136C)	2606 (18)	3277 (23)	3208 (22)
350 F (177C)	1571 (11)	1499 (10)	1410 (10)



Typical Cured Physical Properties Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

#### XIII. Continued - Out Time: Room Temperature Exposure

Scotch-Weld AF 555M Film 0.050 wt., Overlap Shear vs. Out Time

Test Temperature	0 Month PSI (MPa)	6 Months PSI (MPa)	12 Months PSI (MPa)
75F (23C)	5634 (39)	5099 (35)	5164 (36)
277 F (136C)	3016 (21)	3459 (24)	3855 (27)
350 F (177C)	1526 (11)	1650 (11)	1654 (11)

Scotch-Weld AF 555K Film 0.080 wt., Overlap Shear vs. Out Time

Test Temperature	0 Month PSI (MPa)	6 Months PSI (MPa)	12 Months PSI (MPa)
75F (23C)	5765 (40)	5410 (37)	5840 (40)
277 F (136C)	4355 (30)	3519 (24)	4009 (28)
350 F (177C)	2252 (16)	1819 (13)	1981 (14)

Floating roller peel specimens: 1/2" wide, 0.063" back panel, 0.025" skin 2024-T3 bare aluminum, FPL etched and phosphoric acid anodized. Primed with 3M<sup>TM</sup> Scotch-Weld<sup>TM</sup> Adhesive Primer EW-5000.

Scotch-Weld AI	F 555U Film 0.030 wt.,	Floating Roller Peel vs. Out Time
----------------	------------------------	-----------------------------------

Test Temperature	0 Month PIW (N/25mm)	6 Months PIW (N/25mm)	12 Months PIW (N/25mm)
-67F (23C)	22 (97)	20 (89)	24 (107)
75F (136C)	38 (169)	35 (156)	30 (133)
180 F (177C)	39 (173)	38 (169)	40 (178)

Scotch-Weld AF 555M Film 0.050 wt., Floating Roller Peel vs. Out Time

Test Temperature	0 Month PIW (N/25mm)	6 Months PIW (N/25mm)	12 Months PIW (N/25mm)
-67F (23C)	25 (111)	27 (120)	20 (89)
75F (136C)	37 (165)	36 (160)	36 (160)
180 F (177C)	39 (173)	40 (178)	40 (178)

Scotch-Weld AF 555K Film 0.080 wt., Floating Roller Peel vs. Out Time

Test Temperature	0 Month PIW (N/25mm)	6 Months PIW (N/25mm)	12 Months PIW (N/25mm)
-67F (23C)	20 (89)	21 (93)	24 (107)
75F (136C)	31 (138)	32 (142)	36 (160)
180 F (177C)	29 (129)	40 (178)	41 (178)



Typical Cured Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

XIV. Out Time: RDA vs. Room Temperature Exposure

Test Equipment: Rheometric Dynamic Analyzer. Prequency = 1 Hz Heat-up Rate = 5°C/min. Strain = 0.2% Data Collection Frequency = 30 sec. Construct = 3M<sup>7M</sup> Scotch-Weld<sup>7M</sup> Structural Adhesive Film AF 555 0.05 wt.

Scotch-Weld AF 555U Film 0.030 Wt.

	Minimum Viscosity (Pa*s)	Temperature @ Minimum Viscosity F (C)	Time @ Minimum Viscosity (Min.)
Initial	1.44	332 (167)	29
3 Months	1.22	336 (169)	29
6 Months	1.85	332 (167)	28
9 Months	1.66	329 (165)	28
12 Months	1.85	332 (167)	28

Scotch-Weld AF 555M Film 0.050 Wt.

	Minimum Viscosity (Pa*s)	Temperature @ Minimum Viscosity F (C)	Time @ Minimum Viscosity (Min.)
Initial	8.86	338 (170)	29
3 Months	7.96	336 (169)	29
6 Months	11.27	332 (167)	29
9 Months	11.05	336 (169)	28
12 Months	7.85	338 (170)	29

Scotch-Weld AF 555K Film 0.080 Wt.

	Minimum Viscosity (Pa*s)	Temperature @ Minimum Viscosity F (C)	Time @ Minimum Viscosity (Min.)
Initial	4.53	332 (167)	29
3 Months	4.78	329 (165)	28
6 Months	4.36	327 (164)	28
9 Months	5.17	327 (164)	28
12 Months	5.84	324 (162)	27



 Typical Cured
 Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

#### XV. Out Time: 90°F / 50% RH Exposure

DSC vs. Out Time @ 90°F (32°C) / 50% RH Samples of 3M<sup>vs</sup> Scotch-Weld<sup>vs</sup> Structural Adhesive Film AF 555U 0.035 wt. and AF 555M 0.050 wt. were conditioned @ 90°F (32°C) / 50% RH for 60 days. Equipment: Perkin Elmer DSC 7 Ramp Rate: 10°C/min.

#### Scotch-Weld AF 555U Film 0.035 wt. Unsupported

	Onset Temperature °F [°C]	Delta H [J/g]	Peak Exotherm Temperature °F [°C]
initial	315 [157]	289	334 [168]
14 days	315 [157]	296	331 [166]
21 days	313 [156]	280	336 [169]
39 days	313 [156]	302	331 [166]
60 days	311 [155]	290	331 [166]

#### Scotch-Weld AF 555M Film 0.05 wt. Supported

	Onset Temperature 'F ['C]	Delta H [J/g]	Peak Exotherm Temperature "F ["C]
initial	315 [157]	289	340 [171]
14 days	313 [156]	287	336 [169]
21 days	315 [157]	287	336 [169]
39 days	315 [157]	290	336 [169]
60 days	307 [153]	300	331 [166]

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 Typical Cured
 Note: The following technical information and data is based on limited 3M testing conditions and should not be used for specification purposes.

XV. Continued - Out Time: 90°F / 50% RH Exposure

Open Time Data – Minimum viscosity vs. out-time at 90°F (32°C)/50% RH Test Equipment: Rheometric Dynamic Analyzer. Frequency = 1 Hz Heat-up Rate = 5°C/min. Strain = 0.2% Data Collection Frequency = 30 sec. Construct = 3M<sup>TM</sup> Scotch-Weld<sup>TM</sup> Structural Adhesive Film AF 555 0.05 wt.

	Time to Minimum Viscosity (min)	Eta* @ Minimum Viscosity (P)
Initial	24.133	1.58E+01
14 days	24.133	1.60E+01
21 days	23.467	2.02E+01
39 days	23.9	1.75E+01





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#### 3M<sup>\*\*</sup> Scotch-Weld<sup>\*\*</sup> Structural Adhesive Film AF 555

Product Application	Note: While this information is provided as a general application guideline based upon typical conditions, it is recognized that no two applications are identical due to differing assemblies, method of heat and pressure application, production equipment and other limitations. It is therefore suggested that experiments be run, within the actual constraints imposed, to determine optimum conditions for your specific application and to determine suitability of product for particular intended use.
XVI. Surface Prepar A thoroughly cl performance. Cl metal surfaces a	ation saned, dry, grease-free surface is essential for maximum eaning methods that produce a break free water film on re generally satisfactory.
A. Alum anodi are pr FPL I FPL I	inum: Phosphoric acid anodize (3M Test Method C-2780), Chromic acid te with or without a chromate seal (3M Test Methods C-2801 or C-2782) eferred for maximum joint durability in moist environments. Optimized ach has also demonstrated improved durability performance. Optimized ach – 3M Company (3M Test Method C-2803 or ASTM D 2651)
	<ol> <li>Alkaline degrease – Oakite* 164 solution 9-11 oz/gallon of water at 190° ± 10°F for 10 to 20 minutes. Rinse immediately in large quantities of cold running water (3M Test Method C-2802).</li> <li>*Available from Chemetall Oakite, Berkeley Heights, NJ.</li> </ol>
	2. Optimized FPL Etch Solution (1 liter):
	Material Amount Distilled Water 700 ml plus balance of liter (see below) Sodium Dichromate 28 to 67.3 grams Sulfuric Acid 287.9 to 310.0 grams Aluminum Chips 1.5 grams/liter of mixed solution
	Note: Review and follow safety and precautionary information provided by chemical supplier prior to preparation of this etch solution.
	To prepare 1 liter of this solution, dissolve sodium dichromate in 700 ml of distilled water. Add sulfuric acid and mix well. Add additional distilled water to fill to 1 liter. Heat mixed solution to 66 to 71°F (150 to 160°F). Dissolve 1.5 grams of 2024 bare aluminum chips per liter of mixed solution. Gentle agitation will help aluminum dissolve in about 24 hours.
	To FPL etch panels, place them in the above solution at 150 to 160°F (66 to 71°C) for 12 to 15 minutes.
	3. Rinse immediately in large quantities of clear running tap water.
	<ol> <li>Dry – Air dry approximately 15 minutes followed by a force dry at 140°F (maximum).</li> </ol>
	5. Current theory suggests that both surface structure and chemistry play a significant role in determining the strength and permanence of bonded structure. It is therefore advisable to bond or prime freshly cleaned surfaces as early as possible after preparing to avoid contamination and/or mechanical damage.

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3M<sup>as</sup> Scotch-Weld<sup>as</sup> Structural Adhesive Film AF 555

XVI. Continued - Surface Preparation

#### **B. Aluminum Honeycomb Core**

- Soak in clean aliphatic naphtha (conforming to TT-N-95A) for five minutes at room temperature. Dry 10 minutes at 140°F (maximum).
- 2. Optional Immerse in etching solution above for 2 minutes  $155 \pm 5^{\circ}F$ .
- Rinse, air dry and force dry in a similar manner to skins.
- C. Titanium CP or 6AI 4V both Turco<sup>®</sup> 5578-L<sup>\*</sup> and improved phosphate fluoride processing have been used successfully with 3M<sup>™</sup> Scotch-Weld<sup>™</sup> Structural Adhesive Film AF 555.
  - 1. Vapor hone 140 grit in water rinse thoroughly with clear running tap water.
  - 2. Degrease solvent or alkaline process.
  - 3. Immerse for 15 minutes at 185 ± 5°F in the following bath:
    - Turco\* 5578-L 420 grams
    - Distilled water Balance to make 1 liter
  - Immerse for 1 minute in 170 ± 5°F distilled water.
  - 5. Spray rinse for 5 minutes in hot tap water ~ 130°F.
  - 6. Air dry for 10 to 20 minutes.
  - 7. Force dry for 15 minutes at 140°F (maximum).
  - 8. It is advisable to bond or prime freshly cleaned surfaces within four hours.
  - \*Available from Henkel North America.

D. Stainless Steel - Type 301

- 1. Vapor hone 140 grit in water.
- 2. Rinse thoroughly in clear running tap water.
- 3. Alkaline degrease see procedure above.
- 4. Rinse thoroughly in clear running tap water.
- 5. Immerse for 10 minutes at 75 ± 5°F in the following bath:
- Distilled Water 73-95 oz/gal
  - Nitric Acid 42\* Be 30-50 oz/gal
  - Hydrofluoric Acid 70% 3-5 oz/gal
- 6. Rinse thoroughly in clear running tap water.
- 7. Air dry for 10-20 minutes.
- 8. Force dry for 15 minutes at 150°F.
- 9. Bond or prime within four hours after preparing.
- E. Cured fiberglass or carbon fiber reinforced epoxy resin based reinforced
- plastic.
- Abrade with 180 grit paper or 3M<sup>™</sup> Scotch-Brite<sup>™</sup> Scour Pad (do not cut through resin into reinforcing fibers).
- 2. Degrease using acetone or using an unsized cheesecloth pad.
- 3. Air dry for two hours minimum.



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#### 3M<sup>™</sup> Scotch-Weld<sup>™</sup> Structural Adhesive Film AF 555

#### XVIL Primers

For most applications, use of a corrosion inhibiting primer is suggested to obtain maximum bond durability in moist, corrosive environments. 3M<sup>TM</sup> Scotch-Weld<sup>TM</sup> Structural Adhesive Primers EW-5000, EW-5000AS, and EC-3917 have all been successfully used with 3M<sup>TM</sup> Scotch-Weld<sup>TM</sup> Structural Adhesive Film AF 555. Because of its characteristics which allow both spray and brush application methods, either Scotch-Weld EW-5000 or EW-5000AS are normally suggested for use with Scotch-Weld AF 555 films. For suggested application techniques, refer to the respective primer data sheets.

#### **Primer Coverage**

For the primers noted above, the optimum mechanical property test performance with Scotch-Weld AF 555 Film will normally be found with uniform primer coverage in the 1-3 g/m<sup>2</sup> range (dry weight). This is approximately 0.1 mils as measured by an Isometer\*. As the primer weight is increased a gradual decrease in low temperature peel strength will be found along with increasing levels of cohesive fracture in the primer layer (exception: properly controlled 180° T-Peel does not normally show this effect). Where specific tests and required strength levels are involved, a few simple experiments with varied primer coverage will be required to establish an allowable primer coverage range. Further applications can then be controlled by correlating color or thickness standards for the acceptable range. \*Isometer from Forster Instruments, Ontario, Canada.

#### Scotch-Weld EW5000 & EW5000 AS Primers Application

The following cycle is suggested for these primers when used with Scotch-Weld AF 555 films:

5000 (Secondar 200	EW5000 & EW5000 AS	EC-3917:
Cured Thickness	0.10-0.28 mils	0.10-0.20 mils
Air Dry	30 minutes	60 minutes
Force Dry	180 ± 5°F for 30 ± 5 minutes	250 ± 5°F for 60 ± 5 minutes

#### XVIII. Adhesive Film Application

Care should be taken during application to avoid contamination of the adhesive and substrates by any substances which will interfere with the wetting action of the adhesive.

#### Layup:

#### A. Scotch-Weld AF 555 U, M, or K Films

- Cut a portion of film sufficient for the assembly from the stock roll with protective liner(s) in place.
- If the film has one protective liner, place the exposed adhesive against the substrate using the liner as a protective cover. If two liners are present, remove one and follow as above.
- Position film and rub out all air between the adhesive and the substrate. Use of a rubber roller will facilitate this process.
- 4. Remove protective liner.
- 5. Complete assembly being careful to avoid trapping air and cure.



#### 3M<sup>\*\*</sup> Scotch-Weld<sup>\*\*</sup> Structural Adhesive Film AF 555

XIX.	Cure Conditions & Characteristics				
	3M™ Scotch-Weld™ Structural Adhesive Film AF 555 is designed to provide				
	short cure times in the 300 to 355°F temperature range. While performance outside				
	this cure temperature range has not been fully investigated, limited results suggest				
	that cure temperatures as high as 375°F may be used as well as longer cure times at				
	200°F (6 hrs.) to obtain useful performance.				
	A. Standard Cure Cycle for Positive Pressure (Antoclave) Cure - 4.5°F/min. rise rate to 355 ± 5°F.				
	<ul> <li>Vacuum bag target: 28 inches Hg.</li> </ul>				
	<ul> <li>Release (vent) vacuum bag pressure when positive pressure reaches a level of 15 psi.</li> <li>Positive pressure target: 15-20 psi. Pressures as high as 45 psi can be used. If 45 psi pressure is being used to cure overlap shear specimens, shimming must be used to optimize bond line thickness.</li> </ul>				
	<ul> <li>Soak time: 120 minutes ± 5 min. @ 355°F bond line temperature.</li> <li>Cool down @ 10°F/min. to 75°E</li> </ul>				
	<ul> <li>Release positive pressure when hand line temperature reaches 100°F</li> </ul>				
	B. Weight Loss During Cure (3M Test Method C-274):				
	Less than 1% (60 min at 250°F)				
	C. Cure Time and Temperature				
	For temperatures from 325 to 355°F, a cure time of 120 minutes at temperature				
	is suggested. Following cure, it is suggested that pressure be maintained until				
	the assembly has been cooled to 100°F or below.				
	D. Heat up rate				
	Bond line temperature rise rates between 1°F/min. and 20°F/min. have been used successfully with Scotch-Weld AF 555 films. It must be noted that hot entry cures				
	at 300°F and above can be expected to produce reduced performance due to formation of bond line porosity.				
	E. Cure Pressure				
	1. Positive Pressure Cures				
	During cure, pressure is required to keep parts in alignment and to overcome distortions and thermal expansion of the adherends. When bonding honeycomb assemblies with non-perforated core, pressure is required to overcome the thermal expansion of air in the honeycomb cells. Positive pressure between 20 and 80 psi have been used successfully with 3M <sup>TM</sup> Scotch-Weld <sup>TM</sup> Structural Adhesive Film AF 555. For very small area bonds, however, pressures at the higher end of this range may produces excessive squeeze out and adhesive bond line starvation. For large solid panel constructions which are autoclave cured, application of vacuum for 15 to 20 minutes prior to application of heat and pressure is suggested to assist in removing any residual air trapped in the assembly. Normally, the vacuum is released following application of positive pressure @ 15-20 psi. For problem assemblies, maintain the vacuum during the heatup cycle to about 130 <sup>TF</sup> to further assist in providing void free bonds. <b>2. Vacuum Curine</b>				
	Scotch-Weld AF 555 films can be successfully cured using vacuum cure techniques. For performance comparable to positive pressure curve. Scotch. Weld				

Scotch-Weld AF 555 films can be successfully cured using vacuum cure techniques. For performance comparable to positive pressure cures, Scotch-Weld AF 555 films should be cured using a vacuum level in the range of 8-22 inches of mercury. Higher vacuum levels yield excessive porosity and corresponding strength reductions. Scotch-Weld AF 555M versions have shown a high level of performance retention across the 10-25 inches of mercury vacuum level range.

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#### 3M<sup>™</sup> Scotch-Weld<sup>™</sup> Structural Adhesive Film AF 555

XX. Complimentary 3M Products for use with Scotch-Weld AF 555 Film 3M™ Scotch-Weld Adhesive Primer EW-5000 3M<sup>TM</sup> Scotch-Weld Adhesive Primer EW-5000 AS 3M™ Scotch-Weld Adhesive Primer EC-3917 3M™ Scotch-Weld Core Splice Adhesive AF-3024 3M™ Scotch-Weld Void Filling and Edge Sealing Compound EC-3524 B/A

Precautionary Information	Refer to Product Label and Material Safety Data Sheet for health and safety information before using this product. For additional health and safety information, visit www.3M.com/mads or call 1-800-364-3577 or (651) 737-6501.						
Additional Information or To Order							
	Australia 61-2-498-9711 tel 61-2-498-9710 fax	Austria 01-86686-298 tel 01-86686-229 fax	Brazil 55 19 3838-7876 tel 55 19 3838-6892 fax	Canada 800-410-6880 ext. 6018 tel 800-263-3489 fax			
	China 86-21-62753535 tel 86-21-62190698 fax	Denmark 45-43-480100 tel 45-43-968596 fax	France 0810-331-300 tel 30-31-6195 fax	Germany 02131-14-2344 tel 02131-14-3647 fax			
	Italy 02-7035-2177 tel 02-7035-2125 fax	Japan 03-3709-8245 tel 03-3709-8743 fax	Korea 62-3771-4114 tel 62-786-7429 fax	Netherlands 31-71-5-450-272 tel 31-71-5-450-280 fax			
	South Africa 11-922-9111 tel 11-922-2116 fax	Spain 34-91-321-6000 tel 34-91-321-6002 fax	Switzerland 01-724-9114 tol 01-724-9068 fax	United Kingdom (0) 161-237-6174 tel (0) 161-237-3371 fax			
	WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. User is responsible for determining whether the 3M product is fit for a particular purpose and suitable for user's method of application. Please remember that many factors can affect the use and performance of a 3M product in a particular application. Please remember that many factors can affect the use and performance of a 3M product is product september of the user is not be bonded with the product, the surface proparation of those materials, the product selected for user, the conditions in which the product is used, and the time and environmental conditions in which the product is expected to perform are among the many factors that can affect the use and performance of a 3M product. Given the variety of factors that can affect the use and performance of a 3M product, some of which are uniquely within the user's knowledge and control, it is essential that the user evaluate the 3M product to determine whether it is fit for a particular purpose and suitable for the user's method of application.						
Limitation of Remedies and Liability	If the 3M product is proved to be defective, THE EXCLUSIVE REMEDY, AT 3M'S OPTION, SHALL BE TO REFUND THE PURCHASE PRICE OF OR TO REPAIR OR REPLACE THE DEFECTIVE 3M PRODUCT. 3M shall not otherwise be liable for loss or damages, whother direct, indirect, special, incidental, or consequential, regardless of the legal theory asserted, including, but not limited to, contract, negligence, warranty, or strict liability.						
	This product was menufactured under a 3M quality standard registered under A89100 standards.						
3M							
Aerospace and Alrcraft Malm SM Center, Building 223-1N-14 St. Paul, MN 55144-1000 1-800-235-2378 www.SM.com/serospace	banance Division Plasse © 3M 67-970	Recycle. Printed in U.S.A. 2007. All rights reserved. 30-0069-3					

Figure A18. Scotch-Weld AF555M Film Adhesive Material Properties

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The Al honeycomb fill material used was procured from Texas Almet part number

3.1 1/8 .0007P 5052 (3.1 pcf), 1/8-inch hexagonal cell size, 0.0007-inch foil gauge,

P = perforated, 5052 Al alloy). The ROHACELL<sup>®</sup> foam used was ROHACELL<sup>®</sup> 200 WF, which is a closed-cell rigid polymethacrylimade foam and was procured from Evonik Industries

(reference Figure A19 for the ROHACELL® foam material properties).



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## Product Information

### **ROHACELL® WF**

#### Polymethacrylimide Foam

ROHACELL® WF is a closed-cell rigid foam based on polymethacrylimide (PMI) chemistry, which does not contain any CFC's.

ROHACELL® WF has been designed for use primarily in aerospace applications; in addition to conforming to our material specification sheet, it satisfies the usual industry requirements such as MIL and CMS specifications.

ROHACELL® WF rigid foam can be processed at pressures of up to 0.7 MPa and temperatures of up to 130°C. It is therefore highly suited for autoclave prepreg processing and all typical resin infusion processes.

After heat treatment, ROHACELL® WF can even tolerate curing temperatures of 180°C at a pressure of 0.7 MPa.

The thermo-formability of ROHACELL\* provides a tremendous manufacturing advantage.

ROHACELL® WF is also easy to shape by machining.

For further information, please contact our experts by phone +49 6151 18 1005 or e-mail rohacell@evonik.com

RCHACELL® - registered trademark of the Evonik Rohm GmbH

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Properties of R	CHACELL® 1	WF				
Properties	Unit	ROHACELL® 51 WF	RCHACELL® 71 WF	ROHACELL* 110 WF	ROHACELL® 200 WF	Standard
Density	kg/m <sup>3</sup>	52	75	110	205	150 845
	lbs./cu.ft.	3.25	4.68	6.87	12.81	ASTM D 1622
Compressive strength	мра	0.8	1.7	3.6	9.0	150.844
	psi	116	246	522	1305	ASTM D 1621
Tensile strength	мра	1.6	2.2	3.7	6.8	150 527-2
	psi	232	319	536	986	ASTM D 638
Shear strength	MPa	6.8	1.3	2.4	5.0	DIN 53294
	psi	116	188	348	725	ASTM C 273
Elastic modulus	MPa	75	105	180	350	150 527-2
	psi	10,875	15,225	26,100	50750	ASTM D 638
Shear modulus	MPa	24	42	70	150	DIN 53294
	psi	3,480	6,090	10,170	21750	ASTM C 273
Strain at break	56	3.0	3.0	3.0	3.5	ISO 527-2
						ASTM D 638

Technical data of our products are typical values for the nominal density.

\* = registered trademark

This information and all technical and other admice are based on Exercisity present knowledge and experience. However, Exercis assumes no liability for such information or advice, including the extent to which such information or advice may robute to thisd party implicitual property rights. Even it measures the right to make any changes to information or advice may robute to thisd party implicitual property rights. Even it measures the right to make any changes to information or advice may when the third party implicitual property rights. Even it measures the right to make any changes to information or advice intervent. There are no advice the term of the consequent advice to its fitness the a particular perpressive even of such propessive of advice there is for a sole responsibility to an angle for exercise such as a distingt of all products provide spectra to take near sole advice to take near and taking of all products to disting product, and does not length that similar geoducts could not be used.

Evonik Industries AG. Performance Polymers. 64293 Darmstadt Germany Phone: +49.6151 18–1005. E-mail rohacell@evonik.com www.rohacell.com



Figure A19. ROHACELL<sup>®</sup> Foam WF 200 Material Properties


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A2.3 Test Support Hardware Materials

Mounting accelerometers to the test panels is critical for ensuring acquiring quality acceleration data. The accelerometers must be fully seated 360° for optimal response. For the initial pathfinder tests (using the 0.187-inch Al plate) the plate was drilled and tapped for 1/4-28 thread and the PCB350 accelerometers were mounted and torqued directly to the Al plate. With the monolithic composite panels it is not possible to mount the accelerometers directly to the test panel and ensure they will remain installed during the pyroshock event. The approach for mounting the accelerometers the monolithic panel was to drill and tap the composite panels with a 7/16-14 thread and to procure steel inserts with a 7/16-14 outer diameter thread and an inner diameter thread of 1/4-28. Figure A20 shows the threaded inserts that were used for all of the monolithic panel tests. The inserts were threaded into monolithic composite panels until flush with the front surface of the panel and bonded in place using Hysol<sup>®</sup> 9394 adhesive. The locking keys were not use and were removed after installation of the inserts.



**Heavy Duty Stainless Steel** 

# Figure A20. Threaded Insert for Accelerometer Mounting

The composite sandwich panels produced new challenges for mounting the accelerometers to the Group II and Group III test specimen. The installation method chosen was to procure blind threaded inserts, which are potted in the sandwich panel such that the top of the insert is flush with the front facing composite face sheet. Mounting of the accelerometers consisted of threading into the insert and torque to specified torque value. Figure A21 shows the blind insert that was used to install the accelerometers to the composite sandwich panel. Figures A22 and A23 depict examples of the ROHACELL<sup>®</sup> Foam and Al honeycomb sandwich panels prior to insert installation, respectively.

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					OF MARK	ETING NJ RELEAS WRITTE	ASTERS INC IED WITHOUT IN PERMISSION
	TA	BLE I			-	TAB	LEII
SIZE	T THREAD	ØA	BREF	INSTALLATION HOLE SIZE		LENGTH DASH NO.	L
04	1120-40UNJC-38	-	150			-240	.240
06	.1380-32UNJC-38	560		562-565		-310	.310
80	.1640-32UNJC-3B		.160			-375	.375
3	.1900-32UNJF-3B					-565	.565
4	.2500-26UNJF-38	.686	.180	.687690	1	-XXX	XXXL
CODE	CARBON STEEL	ER ASTM	5085				
8	CARBON STEEL	ER ASTM	5085			ENGINEERING POLYMER, PAUROLYAMIDE JAUDE)	
c	CORROSION RES IN ACCORDANCE OR AM35540	ISTANT ST WITH AST	EEL M A582	EL PASSIVATE PER AMS 2700, AND SOLID FILM LUBE PER AS 5272, TYPE 1		ASTM D 5204 PA000R03AS531E11FB41 TORLON 4203L4IF	
TES: UNI	LESS OTHERWISE SPI NCES, UNLESS OTHEI SSIVE BACKED INSTA IEET LOCKING TORQU	CIFIED WISE SPE LLATION T JE REQUIR	CIFIED, AB PT-7 EMENTS CATES N	JOCX = 1.010 IS FURNISHED WITH EJ S OF NASM25027. ION LOCKING NUT.	ACH INSERT.		
AN ADHI PARTS N SUFFIX P MAXIMU	N TO BASIC PART NUM	TSHOULD	NOT EX	CEED "L" MINUS .060".			
AN ADHI PARTS N SUFFIX P MAXIMU	N TO BASIC PART NUN M BOLT ENGAGEMEN BOLT ENGAGEMEN BATE	NON 04/26	NOT EX	CEED "L" MINUS .060".	INSERT, PO	TTED	-IN TYPE
AN ADHI PARTS N SUFFIX P MAXIMU	N TO BASIC PART NUM M BOLT ENGAGEMEN BOLT ENGAGEMEN BATE DRAWN	NON 04/26	NOT EX 196	CEED "L" MINUS .060".	INSERT, PO	DTTED	-IN TYPE

Figure A21. Clipnut Sandwich Panel Blind Insert for Accelerometer Mounting

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Composite Materials Subjected to Pyroshock Loading



Figure A22. ROHACELL<sup>®</sup> Foam Sandwich Panel Prepped for Insert Installation

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**Composite Materials Subjected to Pyroshock Loading** 





Figure A23. Al Honeycomb Sandwich Panel Prepped for Insert Installation

For subjection of the composite panels to test, the panels are suspended at the top two corners of the panels using straps and shackles, with 1/2-inch fasteners. Since the compressive strength of the composite sandwich panels is relatively low, it is not possible to torque the 1/-2 bolt and nut to 55 foot-pounds (ft-lb). To resolve this issue stainless steel sleeves were procured and machined to specific lengths so the sleeve would be just under flush with the backside composite face sheet to accommodate the fastener torque load. Initially, the sleeve with the flange was machined to length and bonded to the through hole machined in the sandwich panel. After the first panel was fabricated in this manner, it was decided to machine the sleeve to remove the flange and not bond them to the panel. The sleeves were inserted into the through holes in the panel during assembly of the panel into the test fixture. The sleeves were re-usable and sleeve pairs were machined in ~ 0.010-inch length increments from 1.070 inches up to 1.140 inches. Figure A24 provides detail on the stainless steel composite sandwich panel mounting sleeve.





Note: A dash number -125 with a length of -20 fabricated from passive stainless steel was used.

Figure A24. Witten Company, Through-Hole Sleeve for Mounting Sandwich Panels



# **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

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1.0

In addition to the inserts and sleeves, the test support hardware for the pyroshock testing included the sacrificial LSC plate, the backing support plate, and the LSC standoff shims. The LSC plate and the LSC standoff shims were fabricated from 5052 Al alloy (except for the composite LSC plates as noted in Table 7.0-4 (test Group III)) and were expended in test, thus not re-usable. Two backing support plates were fabricated from 5052 Al alloy and were re-used through the entire test series.

# A2.4 Melamine Acoustic Foam

The MAF tests were not included in the baseline task assessment plan and were added to the task assessment plan in the August 15, 2014, scope update to the assessment plan. The MAF used for these tests was procured from Soundcoat in accordance with the MSFC generated melamine foam drawing (reference Figure A12-2). The acoustic foam was configured with a thin layer of conductive Kapton<sup>®</sup> film covering both the front and backsides of the acoustic foam. Figure A25 provides the material properties of the MAF and Figure A26 provides information on the Kapton<sup>®</sup> film.





Product Description (w/ Features & Benefits):

SOUNDFOAM ML is a lightweight, flexible, open-cell, melamine based acoustic quality foam having excellent flame\* and heat resistance. It exhibits a very low degree of flammability, does not drip upon ignition, ceases to burn after removal of ignition source, and produces a minimum amount of smoke. Compared with some glass-fiber based acoustical products, SOUNDFOAM ML has better strength, lower compression set, and higher resiliency. It is recommended for use as acoustic or themal insulation in aerospace, marine, or ground units, etc., where light weight, heat resistance, and fire safety are of the utmost concern. It is available plain or with decorative and protective surface finishes of reinforced aluminized polyester film, Tedlar®, Nomex®, etc. For customer convenience, the foam is supplied with one of several high performance pressure-sensitive adhesives for ease of installation. Soundfoam ML is available in standard sheet sizes or in custom sheet sizes or as custom cut parts.

#### How It Works:

The sound absorption performance of elastic porous materials is determined mainly by the porosity and airflow resistance (air permeability) of the materials. Sound absorption data for various surface finishes are available upon request. Following are typical sound absorption curves.





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#### Physical Properties:

Chemical Type:	Flexible Melamine Foam
Color	Grev
Thickness mm (in ):	Std 64 (0.25) 12 7 (0.5) 19 0 (0.75) 25 4 (1) and 50 8 (2)
Sheet Size mm (in ):	Std 1219 x 610 (48 x 24) or 2428 x 1219 (96 x 48)
Density haim <sup>2</sup> (lb/9 <sup>2</sup> ):	6 (0 562) nor ASTM D 2574-77 Test A
Tenails Stemath & Do (nai)	120 (12) not ASTALD 35 (477) Tel. A
Figure Strength, Kra(ps).	20 (10) per ASTA D 3574-77 Test E
Elonganon, 76:	20 per ASIM D 35/4-77 Test E
Tear Strength, Nom (10m)	87 (0.5) per ASTM D 3574-77 Test P
CLD (25%), N/mm* (psi):	0.01 (1.4) per ASIM D 35/4-77 Test C
Compression Set (50%), %	30 per ASTM D 3574-77 Test D
Thermal Conductivity,	46 (0.25) per ASTM C 117 at 24°C (75°F)
kcal.m/hr.m". "C (BTU.in/hr.ff". "F):	
Service Temperature:	-43° to 200°C (-45° to 392°F)
Flame Resistance*:	<ul> <li>FAR 25.853 (b) Vertical Burn Test</li> </ul>
	<ul> <li>Burn Length: 2.54 cm (1.0 in.)</li> </ul>
	<ul> <li>Post Burn Time: 0 s, no dripping</li> </ul>
	<ul> <li>FAR 25.856(a)</li> </ul>
	o Pass
	• UL-94
	<ul> <li>Meets HF-1 and V-0 classification requirements</li> </ul>
	ASTM F 84 Tunnel Test
	<ul> <li>Flame Sorrad: 7.5</li> </ul>
	o Smole Developed: 16.9
	APTA E 162
	<ul> <li>ASTALE 162</li> </ul>
	0 <25
	<ul> <li>ASIME 662</li> </ul>
	0 <100
Airflow Resistivity:	13410 Rayls/m

Typical Sound Absorption Performance:

Sound absorption coefficients measured per ASTM C 384:

Thickness \ Frequency	125	250	500	1000	2000	4000
6.4 mm (0.25 in)	0.05	0.05	0.10	0.20	0.39	0.81
12.7 mm (0.5 in)	0.13	0.15	0.26	0.43	0.76	0.93
25.4 (1.0 in)	0.18	0.25	0.50	0.82	0.97	1.00

For further information regarding this product, please contact our Technical Support Department at 1-800-394-8913, ext. 147.

Visit us on the web at <u>www.soundcoat.com</u> to see our complete line of absorption, damping, and barrier materials for the OEM marketplace.

Soundcoat

Rev 3/13

...... Keeping it Quiet for 40 years

The information contained here in is based on laboratory test data developed by or for Soundcost and is believed to be reliable, but its assurance or completeness is not guaranteed. The buyer must test thin product to distributing the bits specific application believe use. Our Y was a Soundcost product after thoroughly compliang instructors on the data sheet for the specific product SOUNDCOAT DISCLAMS ANY RESPONSIBILITY FOR: I) WAREANTIES OF FITNESS AND PURPORE, 2) VERBAL RECOMMENDATIONS, 3) CONSEQUENTIAL DAMAGES FROM USE AND 4) VICLATION OF ANY PATENTS OR, 5) CONSEQUENTIAL DAMAGES FROM USE AND 4) VICLATION OF ANY PATENTS OR TRADEMARKS HELD BY OTHERS.

\* This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions. The Federal Trude Commission consider that there are no existing test methods or standards regarding flammability that are accurate indicators of the performance of cellular plastic materials under actual fire conditions. Any result of existing methods, such as ASTM D 1692 and UL-94, are intended only as a measurement of the performance of such materials under specific, controlled conditions.

Figure A25. MAF Material Properties

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DI	EXPENDABLE L	G COMPANY AUNCH SYSTEMS MATERIAL REC	ORD	DPM	DPM8929
INTLE					
FILM, POLYIMIDE,	BLACK, CONDUCTIVE		terr Marson Mars		
OPI MO14 AFFECTED:	MTR RCOURED:	RECEIVING TEST		MSDS REQU	IRED
TES X NO	YES X NO		QUARTERLY		X YES NO
Gonoral		SPECIFICATION * None		MANUFACTU REQUIRED:	IRER CERTIFICATION
CHECK ONE OF THE FO	LLOWING:		PR	ODUCT	
Suy from rife, and/o	r class, listed only.				
Boy from mig. or from	m any distributor who supplie	a mig. product.			
MANUFACTURER AND/C	RDISTRIBUTOR				
Dupont Films (600) 967–5507			160	XC	
(***) *** ****					
			FIRAN	INVE	
			1146-16	UXC	
init size Roli	QUANTITY TO ORDER NO	W HAZARD FLAG R	STOKAGE LIFE (N Original: Reteat: N/A Max.	105.) 370	N/A F
Roll width of 43 inch 2–18 GHz range an surface resistivity of	es, may be slit to narrowor d supplier DC specificatio 1 300 to 430 ohme/sq.	width as required. Supp on. Supplier to certify m	fier to provide lot les atenial meets film th	t data pertainir Ickness of 1.5	ng to AC resistivity at 5 to 1.8 mile and DC
MAPE INSTRUCTIONS	14/50:	MEC	OUAL IFICATION REPO	ORT NUMBERIS	
WILL THIS OPM REVISI	ON HAVE A COST/SCHEOUL	IMPACT ON MANUFACTUR	UNGY 7 YES	X NO	)
OPM CANCELLATION CO	MMENTS	19	VENTORY DISPOSITIO	N	7 <u></u>
	507003938383		SCRAP		POUND TURN FOR CREDIT
RIGINATOR	ENVIRONMENTAL SE	RVICES APP	ROVED BY		DATE
/s/M. Goodrich	N/A	150	A. Markus		4-18-02
COLUMN STATISTICS	AND REASON		Partie Courtes		
HIMMARY OF CHANGE					
SUMMARY OF CHANGE / Revised to update D	OPM title and reflect buy I	from manufacturer and/o	or distributor listed o	niy.	

Figure A26. MAF Kapton<sup>®</sup> Film Data



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# A3 Fabrication

The EM42 personnel fabricated all of the composite panels at MSFC. The panels were fabricated per the steps listed in MSFC work orders approved by EM42 Engineering and the task assessment technical lead (see Figure A27, A28, and A29 for monolithic, sandwich, and MAF as typical examples). Figure A30 shows a pictorial overview for assembly of a ROHACELL<sup>®</sup> foam sandwich test panel.



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# Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

Title: Pyroshock Pathfinder Work order number: 0320 Panel ID: 0320A001 0320 = Work Order Number 1 = 1M7 Prepreg material fiber type 001 = panel number

Panel Dimensions: 36" x 72", 38 plies Panel Materials: IM7/TC350 6K 5HS, 280 gsm, 42"

#### NOTES:

Only materials listed in the applicable OWIs are permitted in the work area to aid in the
prevention of contamination. Materials containing silicones and tools used with those materials are
prohibited in the work areas.

 Vacuum bag material shall be verified to have no visible contamination prior to installation onto test panel for curing with an inspection distance of 6-18 inches using adequate shop lighting.

 For metallic support hardware, wipe down using lint free clean wiping cloths and Acetone or Methyl Ethyl Ketone (MEK) to remove any potential contamination that could be introduced into the processing.

Identity of test panels shall be maintained throughout processing, photography, and testing.

If any anomalies occur during processing of this panel contact the NASA/EM40 Lead Engineer

immediately and document the occurrence per EM40-OWI-37.

All Kraft paper used through all processing steps will be of the acid-free type.

Table 1. Process and Material Identification Table.

Material	Identifying Numbers	Date Used	Time Out of Freezer	Time Into Freezer	Initials
ІМ7/ТС350	TCAC 23424 LoT #100912-173 Roll #1	11/26/242	6 HRS	-	JN

Material	Identifying Numbers	Within Shelflife (Y/N)	Initials
Airweave	7030010252	Y	TN
Sealant Tape	107# 1062012	Y -	JN
Release Film	45000 Viotet	Y	JN
Peel Ply (striped)	None used	Y	JN
Vacuum Bag	10310299	Y	JN

Process	Date	Time	Initials
Part was bagged	11/27/2012	1:00 pm	TN
Part was placed in autoclave	11/28/2012	9'or Aim	JN



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### Prepreg/Adhesive Preparation

1. Place lint and powder free latex gloves on when handling prepreg at all times. INITIALS JW

 Record out time on NMIH label when removing any frozen material, If label is full, attach another label adjacent to the previous one. Weigh prepreg/adhesive rolls and jot number next to out time also fill out this info in table 1.

3. Allow 4 hours to thaw for large prepreg rolls. Return material to freezer immediately after cutting for your panel to minimize out time.

4. Record ambient temperature and humidity below. Temperature  $\frac{12^{\circ}f}{16^{\circ}f}$ 

Humidity 45 % RA

#### Laminate Construction

1. Environment requirements for temperature and humidity for all steps of lay-up shall be maintained during the operation per the following:

Temperature =  $70 + 5^{\circ}F$ Humidity = 40 - 55%INITIALS: JN

2. Cut a piece of solid release film that is larger than the cut plies. Label the film with the panel ID along with the  $0^{\circ}$ ,  $45^{\circ}$  and the  $90^{\circ}$  ply directional rosette on the edge of the film. Placement of rosette should be placed as seen below. Place the release film on top of the baseplate tool shown in Figure 3.



Figure 1. Rosette Location

3. Lay up plies of IM7/TC350 prepreg placed in the sequence listed in table 1. A vacuum debulk should always be performed after the 1st ply and at 5 ply intervals thereafter. After final debulk, repeat process for the second face sheet.

INITIALS: JN



Version:

Ply #	Time of Debulk	Ply orientation (degrees)	Initial
1		0	JN PT
Debulk for 5 minutes	Start time: 7:00 Stop time: 745		JN PT
2		0	JN AT
3		0	JN PT
4		0	TN PT
5		0	TN PT
Debulk for 5 minutes	Start time: 8:00 Stop time: 8.10	-	JN PT
6		0	JP PT
7		0	JH DT
8 .	1 ··· ···	Ó	TAL OT
9		0	IN PT
10		0	IN PT
Debulk for 5 minutes	Start time: 9:20 Stop time: 9:30		JN PT
11		0	JN PT
12		0	JA PT
13	in the set of the set	0	JN PT
14		0	JN PT
15		0	TN PT
Debulk for 5 minutes	Start time: 10.15 Stop time: 10.2	0	JN PT
16		0	JH PT
17		0	JN PT
18		0	TN PT

## Table 1. Lay-up Sequence and Debulk Locations.

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Lay-Up & Bagging

**Bagging Sequence for Cure:** 

## List of materials

- 1. Tool aluminum, steel, invar, composite (tool plates must be release coated or film covered)
- 2. Release coat or film ~ Frekote 700NC or 770NC, FEP, TEDLAR
- 3. Silicone/Rubber Edge Dams Thicker than laminate
- 4. Laminate
- 5. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- 6. Caul plate aluminum, steel, Invar, silicone rubber sheet (metal caul plates must be release coated or wrapped)
- 7. 2.2 osy polyester breather -1 or more
- 8. Vacuum bag
- 9. Vacuum sealant
- 10. Glass yarn string (alternatively or additionally breather may wrap over top of dam to contact edge)



Figure 3. Lay Up

1. Follow Figure 3 as a guide to panel lay up materials and layer sequence. Ensure curing plate has been solvent wiped to remove potential contaminants using MEK or acetone and clean lint free wipes. Wipe in a linear motion to prevent recontamination. INITIALS: \_\_\_\_\_

2. Install thermocouple to monitor the temperature of the part during cure. Bag part per Figure 3. Before bagging an EM40, engineer must check and sign off. . IN

ITIALS: JN	EM40 ENGINEER INTIALS:	Bwe
	그는 것 같은 아파가 물었다. 같은 것은 것에서 한 것이 있다. 것은 것을 정하는 것은 전 것을 만들었다.	

3. Encompass lay up in vacuum bag in preparation for cure cycle. Pull vacuum at 25 inHg minimum. Leak check vacuum bag by disconnecting the vacuum line and installing a vacuum gauge. Ensure that the leak rate does not exceed 1.0 inHg after five minutes. If leak is detected completely replace vacuum bag and repeat process.

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4. Keep track of which thermocouple wire number is assigned to this panel during the cure by noting here: # 4. Rece of Clave between hay-up Table and Panel. # 5. Front of clave between Kaul Plote and Panel. 5. Cure times and temperature shall be recorded using the autoclave data recorder for traceability. Print the

5. Cure times and temperature shall be recorded using the autoclave data recorder for traceability. Print the recorded cure cycle profile and attach it to the Shop Traveler. Cure the panel using the autoclave per the following cure cycle:

- 75° to 350° @ 3°/min ~= 1 hour 30 min
- 350" hold ~= 2 hour 0 min
- 350° to 75° @ 5°/min ~= 60 min

## Pathfinder Panel Cure Cycle

- Autoclave cure at 90 - 100 psi

### TC350 TOUGHENED EPOXY RESIN SYSTEM: Cure cycla



6. Remove all sharp edges from the as-cured panels using a file, rasp, or abrasive paper. Mark with panel identification, core ribbon direction, 0° orientation, 1.0" from the edge of the panel using a paint pen.

 Record all anomalies or process deviations below and coordinate with EM40 Lead Engineer: *Mone-*

DATE: 11/28/2012 INITIALS: JW

8. Deliver cured panel to EM20 for NDE inspection. Attach results of inspection to the end of this Work Traveller. DATE:  $\frac{1}{28/20}$  DINITIALS:  $\frac{372}{20}$ 

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Provide the results of the NDE inspection to the lead EM40 engineer.
 DATE:\_\_\_\_\_\_ INITIALS:\_\_\_\_\_\_

10. After NDE, use the template to drill center holes (See attached drawing) and drill only two .5162-inch holes that will be required on one end at each corner for hanging the panels DATE:  $\frac{12}{17}$ . An INITIALS:  $\frac{12}{12}$  GB

11. Install/bond provided inserts (#1428SKS) into the center holes of the panel. The inserts shall be flush with the panel op one side. Please remove locking parts of the inserts DATE:  $\frac{12}{18}\frac{12}{12}$  INITIALS:  $\frac{51}{22}$ 

12. Provide a copy of the fabrication traveler to EV32. DATE: <u>12/19/2t 12</u> NITIALS: <u>J</u>

4.

13. Provide cured panel to EV32 DATE: 12/19/2012 INITIALS: JN



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Panel Dimensions: 36" x 72", 36 plies Panel Materials: IM7/TC350 6K 5HS, 280 gsm, 42"

#### NOTES:

- Only materials listed in the applicable OWIs are permitted in the work area to aid in the prevention of contamination. Materials containing silicones and tools used with those materials are prohibited in the work areas.

 Vacuum bag material shall be verified to have no visible contamination prior to installation onto test panel for curing with an inspection distance of 6-18 inches using adequate shop lighting.

- For metallic support hardware, wipe down using lint free clean wiping cloths and Acetone or Methyl Ethyl Ketone (MEK) to remove any potential contamination that could be introduced into the processing.

Identity of test panels shall be maintained throughout processing, photography, and testing.

- If any anomalies occur during processing of this panel contact the NASA/EM40 Lead Engineer immediately and document the occurrence per EM40-OWI-37.

- All Kraft paper used through all processing steps will be of the acid-free type.

Table I. Process and Material Identification Table.

Material	Identifying Numbers	Date Used	Time Out of Freezer	Time Into Freezer	Initials
	TCAC 23424 LOT#10912-173 Roll # =	11/27/2012 12/03/2012		12/02/2012 1:00 p.m	a
IM7/TC350					

Material	Identifying Numbers	Within Shelflife (Y/N)	Initials
Airweave	7030010252	Y	JN
Sealant Tape	LOT# 1662012	Y	JN
Release Film	A5000 11:0/et	Y	TN
Peel Ply (striped)	None used	Y	JN
Vacuum Bag	103102 99	Y	JN

Process	Date	Time	Initials
Part was bagged	11/27/2012	1:00 P.M	JN
Part was placed in autoclave	11/28/2012	9:00 A.m	JN



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#### Prepreg/Adhesive Preparation

1. Place lint and powder free latex gloves on when handling prepreg at all times. INITIALS\_ JA

2. Record out time on NMIH label when removing any frozen material, If label is full, attach another label adjacent to the previous one. Weigh prepreg/adhesive rolls and jot number next to out time also fill out this info in table 1.

3. Allow 4 hours to thaw for large prepreg rolls. Return material to freezer immediately after cutting for your panel to minimize out time.

4. Record ambient temperature and humidity below. 72°F Temperature

Humidity\_ 45 8 RH

#### Laminate Construction

1. Environment requirements for temperature and humidity for all steps of lay-up shall be maintained during the operation per the following:

Temperature = 70 +/- 5°F Humidity = 40 - 55% INITIALS: JN

2. Cut a piece of solid release film that is larger than the cut plies. Label the film with the panel ID along with the 0°, 45° and the 90° ply directional rosette on the edge of the film. Placement of rosette should be placed as seen below. Place the release film on top of the baseplate tool shown in Figure 3.



Figure 1. Rosette Location

3. Lay up plies of IM7/TC350 prepreg placed in the sequence listed in table 1. A vacuum debulk should always be performed after the 1st ply and at 5 ply intervals thereafter. After final debulk, repeat process for the second face sheet.

INITIALS: JU

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Piy #	Time of Debulk	Ply orientation (degrees)	Initial
1	11/30/2012 2:00 6:394 12	3 45	TIL JR
Debulk for 5 minutes	Start time: Stop time:		1010 000
2		-45	50
3		0	TAL
4		0	111
5		45	11/
Debulk for 5 minutes	Start time: 7.'34 Stop time: 8:0.	5	
6		-45	Tel
7		90	-UN
8			JN
9			JA
10			00
Debulk for 5 minutes	Start time: 8:48 Stop time: 8 11	2	JN
11	8110 stop and 7.9	0	JN
12		90	JN
13		90	<u>JU</u>
14		-45	JN
		45	JN.
1.5		0	T
Debuik for 5 minutes	Start time: 10150 Stop time: 12:00		JN .
16		0	TA
17		-45	11/
18		45	171

Begged . 12/03/2012 1:00 P.m



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## Lay-Up & Bagging

#### **Bagging Sequence for Cure:**

### List of materials

- 1. Tool aluminum, steel, invar, composite (tool plates must be release coated or film covered
- 2. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- s. Silicone/Rubber Edge Dams Thicker than laminate
- 4. Laminate
- 5. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- 5. Caul plate aluminum, steel, Invar, silicone rubber sheet (metal caul plates must be release coated or wrapped)
- 7. 2.2 osy polyester breather 1 or more
- 8. Vacuum bag
- 9. Vacuum sealant
- 10. Glass yarn string (alternatively or additionally breather may wrap over top of dam to contact edge)



#### Figure 3. Lay Up

1. Follow Figure 3 as a guide to panel lay up materials and layer sequence. Ensure curing plate has been solvent wiped to remove potential contaminants using MEK or acctone and clean lint free wipes. Wipe in a linear motion to prevent recontamination.

2. Install thermocouple to monitor the temperature of the part during cure. Bag part per Figure 3. Before bagging an EM40 engineer must check and sign off. INITIALS: JU

EM40 ENGINEER INTIALS: Sive

3. Encompass lay up in vacuum bag in preparation for cure cycle. Pull vacuum at 25 inHg minimum. Leak check vacuum bag by disconnecting the vacuum line and installing a vacuum gauge. Ensure that the leak rate does not exceed 1.0 inHg after five minutes. If leak is detected completely replace vacuum bag and repeat process.



#5 Perc! 5. Cure times and temperature shall be recorded using the autoclave data recorder for traceability. Print the recorded cure cycle profile and attach it to the Shop Traveler. Cure the panel using the autoclave per the following cure cycle:

- 75° to 350° @ 3°/min ~= 1 hour 30 min
- 350° hold ~= 2 hour 0 min
- 350° to 75° @ 5°/min ~= 60 min

#### Pathfinder Panel Cure Cycle

- Autoclave cure at 90-100 psl File Nanc! Pyroshock Pathfind # 0320,0002-.CSV

TC350 TOUGHENED EPOXY RESIN SYSTEM: Cure cycle



6. Remove all sharp edges from the as-cured panels using a file, rasp, or abrasive paper. Mark with panel identification, core ribbon direction, 0° orientation, 1.0" from the edge of the panel using a paint per.

7. Record all anomalies or process deviations below and coordinate with EM40 Lead Engineer:

None

DATE: 12/04/2012 INITIALS: JN

8. Deliver cured panel to EM20 for NDE inspection. Attach results of inspection to the end of this Work Traveller. DATE:  $\frac{12}{05}$   $\frac{3}{2}$ -INITIALS: TN

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9. Provide the results of the NDE inspection to the lead EM40 engineer.
DATE: \_\_\_\_\_\_ INITIALS:\_\_\_\_\_\_

10. After NDE, use the template to drill center holes (See attached drawing) and drill only two .5162-inch holes that will be required on one end at each corner for hanging the panels DATE:  $\frac{12}{2}$ -INITIALS:  $\frac{52}{2}$ -INITIALS:

i 1. Install/bond provided inserts (#1428SKS) into the center holes of the panel. The inserts shall be flush with the panel on one side. Please remove locking parts of the inserts DATE:  $\frac{12}{19} \frac{2012}{2012}$  INITIALS: <u>JP</u>

12. Provide a copy of the fabrication traveler to EV32. DATE: 2/2020/2 INITIALS: 5/2

13. Provide cured panel to EV32 DATE: 1/20/2012 INITIALS: JN



Title: Pyroshock Pathfinder Work order number: 0320 Panel JD: 0320A003 0320 = Work Order Number 1 = IM7 Prepreg material fiber type 003 = panel number

Panel Dimensions: 36" x 72", 54 plies Panel Materials: IM7 12K, 150gsm/TC350, 24"

#### NOTES:

Only materials listed in the applicable OWIs are permitted in the work area to aid in the
prevention of contamination. Materials containing silicones and tools used with those materials are
prohibited in the work areas.

Vacuum bag material shall be verified to have no visible contamination prior to installation onto test panel for curing with an inspection distance of 6-18 inches using adequate shop lighting.
 For metallic support hardware, wipe down using lint free clean wiping cloths and Acetone or Methyl Ethyl Ketone (MEK) to remove any potential contamination that could be introduced into the

Identity of test panels shall be maintained throughout processing, photography, and testing.
 If any anomalies occur during processing of this panel contact the NASA/EM40 Lead Engineer

immediately and document the occurrence per EM40-OWI-37.

All Kraft paper used through all processing steps will be of the acid-free type.

Table 1. Process and Material Identification Table. Time Out Time Into Identifying Numbers Material Date Used of Freezer Freezer Initials TCAC 23423 12/11/202-JU FAT 7 12K, 150 55m/7 350 34 1 276 Resin content Roll # 11 IM7/TC350

Material	Identifying Numbers	Within Shelflife (Y/N)	Initials
Airweave	7030010252	Y	IN
Sealant Tape	LOT# 1062012	Y	IN
Release Film	45000 Violet	Y	JH
*Peel Ply (striped)	None used	Y	JP.
Vacuum Bag	10310299	Y	JN

Process	Date	👢 Time	Initials
Part was bagged	12/12/2012	6:30 Am	A
Part was placed in autoclave	12/13/2012	T:00 pm	TN



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Prepreg/Adhesive Preparation

1. Place lint and powder free latex gloves on when handling prepreg at all times. INITIALS  $\mathcal{I}\mathcal{M}$ 

2. Record out time on NMIH label when removing any frozen material, if label is full, attach another label adjacent to the previous one. Weigh prepreg/adhesive rolls and jot number next to out time also fill out this info in table 1.

3. Allow 4 hours to thaw for large prepreg rolls. Return material to freezer immediately after cutting for your panel to minimize out time.

4. Record ambient temperature and humidity below. Temperature 73 °F

Temperature Humidity\_ In R E

## Laminate Construction

1. Environment requirements for temperature and humidity for all steps of lay-up shall be maintained curing the operation per the following:

Temperature =  $70 \pm 5^{\circ}$ F Humidity =  $40 - 55^{\circ}$ INITIALS: <u>TRU</u>

2. Cut a piece of solid release film that is larger than the cut plies. Label the film with the panel ID along with the  $0^{\circ}$ ,  $45^{\circ}$  and the  $90^{\circ}$  ply directional rosette on the edge of the film. Placement of rosette should be placed as seen below. Place the release film on top of the baseplate tool shown in Figure 3.



Figure 1. Rosette Location

3. Lay up plies of the material placed in the sequence listed in table 1. A vacuum debulk should always be performed after the 1st ply and at 5 ply intervals thereafter. After final debulk, repeat process for the second face sheet.

INITIALS: JN 17

3

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Ply #	Ply orientation (degrees)	Initial	
1	45	JN PT	
Debulk 5 minutes	9:22 9:40		
2	-45	JN PT	
3	0	JN PT	]
4	0	JN PT	
5	45	JN PT	
6	-45	JN PT	
Debulk 5 minutes	11:22 12:45		
7	90	JN PT	
8	90	JNPT	
9	45	JN OT	
10	-45	JN PT	7
11	0	JN P+	
Debulk 5 minutes	2:00 2:15		-
12	0	TN PT	-
13	45	TI PT	
14	-45	TU PT	-
14	90	EN PT	-
16	90	TU OT	-
10 Dobulk Eminutor	21.0 7:00	Nr 11	-
Debuik 5 minutes	3.08 5.00	IN PT	-
17	45	FIN PT	<u> </u>
18	-43	JU OT	-
19		TU D	
20	45	Tu or	4
Z1 Debuilt Eminutes	40	pr PI	-1
Debuik 5 minutes	7. 7. 7. 20	JUG	-
22	-45	JU OT	
23		TNOT	-
24	45	TH PT	-
23	-45	LA PI	
Dobulk E minutor	5.01 5.20		
27	0	TH PT	-
27	0	TN PT	_
	-45	TN OT	-1
30	45	TN DI	T I
30	90	TAL DI	=
Debulk 5 minutes	5'550 7'200		12/12
23	00	TU m	

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33	-45	JN PT
34	45	JN PT
35	0	JN PT
36	0	IN PT
Debulk 5 minutes	8:15 8:48	
37	-45	JU PT
38	45	JN PT
39	90	JN PT
40	90	JN PT
41	-45	JN PT
Debulk 5 minutes	9:40 9:58	
42	45	JN PT
43	0	JN PT
44	0	JN PT
45	-45	JN PT
46	45	JN PT
Debulk 5 minutes	11:00 12:15	
47	90	TH PT
48	90	JN YT
49	-45	IN PT
50	45	JN PT
51	0	IN PT
Debulk 5 minutes	1:30 1:40	
52	0	JN PT
53	-45	JN PT
54	45	JN PT



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# Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading Page #: 96 of 793

### Lay-Up & Bagging

#### **Bagging Sequence for Cure:**

## List of materials

- Tool aluminum, steel, invar, composite (tool plates must be release coated or film covered)
- 2. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- 3. Silicone/Rubber Edge Dams Thicker than laminate
- 4. Laminate
- 5. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- Caul plate aluminum, steel, invar, silicone rubber sheet (metal caul plates must be release coated or wrapped)
- 7. 2.2 gsy polyester breather 1 or more
- a. Vacuum bag
- 9. Vacuum sealant
- 30. Glass yarn string (alternatively or additionally breather may wrap over top of dam to contact edge)



Figure 3. Lay Up

1. Follow Figure 3 as a guide to panel lay up materials and layer sequence. Ensure curing plate has been solvent wiped to remove potential contaminants using MEK or acetone and clean lint free wipes. Wipe in a linear motion to prevent recontamination. INITIALS:  $\int M P^{T}$ 

2. Install thermocouple to monitor the temperature of the part during cure. Bag part per Figure 3. Before bagging an EM40 engineer must check and sign off.

INITIALS: JUPT EM40 ENGINEER INTIALS: 18WC

3. Encompass lay up in vacuum bag in preparation for cure cycle. Pull vacuum at 25 inHg minimum. Leak check vacuum bag by disconnecting the vacuum line and installing a vacuum gauge. Ensure that the leak rate does not exceed 1.0 inHg after five minutes. If leak is detected completely replace vacuum bag and repeat process.



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4. Keep track of which thermocouple wire number is assigned to this panel during the cure by noting here: #4-700L #5-Part

5. Cure times and temperature shall be recorded using the autoclave data recorder for traceability. Print the recorded cure cycle profile and attach it to the Shop Traveler. Cure the panel using the autoclave per the following cure cycle:

- 75° to 350° @ 3°/min ~= 1 hour 30 min
- 350° hold ~= 2 hour 0 min
- 350° to 75° @ 5°/min ~= 60 min

## Pathfinder Panel Cure Cycle

- Autoclave cure at 90 - 100 psi

## TC350 TOUGHENED EPOXY RESIN SYSTEM: Cure cycla



6. Remove all sharp edges from the as-cured panels using a file, rasp, or abrasive paper. Mark with panel identification, core ribbon direction, 0° orientation, 1.0" from the edge of the panel using a paint pen.

7. Record all anomalies or process deviations below and coordinate with EM40 Lead Engineer:

DATE: 10/2/11/242 INITIALS: JP

8. Deliver cured panel to EM20 for NDE inspection. Attach results of inspection to the end of this Work Traveller. DATE: 12/14/2017-INITIALS: JV



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9. Provide the results of the NDE inspection to the lead EM40 engineer.
DATE:\_\_\_\_\_\_ INITIALS:\_\_\_\_\_

10. After NDE, use the template to drill center holes (See attached drawing) and drill only two .5162-inch holes that will be required on one end at each corner for hanging the panels DATE:  $\frac{1/b}{13}$  INITIALS:  $\underline{TV}$  GE

11. Install/bond provided inserts (#1428SKS) into the center holes of the panel. The inserts shall be flush with the panel on one side. Please remove locking parts of the inserts DATE:  $\frac{1/7}{13}$  INITIALS:  $\frac{1}{3}$ 

12. Provide a copy of the fabrication traveler to EV32. DATE: ///8//3\_\_\_\_\_INITIALS:\_\_\_\_\_\_

13. Provide cured panel to EV32
DATE:\_\_\_\_\_ INITIALS:\_\_\_\_\_



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**NESC-RP-**12-00783

Title: Page #: 99 of 793 **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading** 

> Title: Pyroshock Pathfinder Work order number: 0320 Panel ID: 0320A004 0320 = Work Order Number = IM7 Prepreg material fiber type 1 004 = panel number

Panel Dimensions: 36" x 72", 27 plies Panel Materials: IM7/TC350 6K 5HS, 280 gsm, 42"

#### NOTES:

Only materials listed in the applicable OWIs are permitted in the work area to aid in the prevention of contamination. Materials containing silicones and tools used with those materials are prohibited in the work areas.

Vacuum bag material shall be verified to have no visible contamination prior to installation onto test panel for curing with an inspection distance of 6-18 inches using adequate shop lighting.

For metallic support hardware, wipe down using lint free clean wiping cloths and Acetone or Methyl Ethyl Ketone (MEK) to remove any potential contamination that could be introduced into the processing.

Identity of test panels shall be maintained throughout processing, photography, and testing. If any anomalies occur during processing of this panel contact the NASA/EM40 Lead Engineer immediately and document the occurrence per EM40-OWI-37.

All Kraft paper used through all processing steps will be of the acid-free type.

Table 1. Process and Material Identification Table.

Material	Identifying Numbers	Date Used	Time Out of Freezer	Time Into Freezer	Initials
	TCAC 23424	R/13/202			
	FM76K5HS,28055	7			
	TC 30 761 750 Res.n				- 5
	207#100912 -173				}

Material	Identifying Numbers	Within Shelflife (Y/N)	Initials
Airweave	70300/0252	Y	TAL
Sealant Tape	LOT# 1062012	Y	TN
Release Film	45000 U.0/8+	Y	TN
A Peel Ply (striped)	None used	Y	TN
Vacuum Bag	10310299	Y	FN

Process	, Dạte	Time	Initials
Part was bagged	12/14/2012	1:30	JN PT
Part was placed in autoclave	12/17/2012	6:00 Am	JNPT

NESC Request No.: TI-12-00783



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#### Title: Page #: 100 of 793 **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

## Prepreg/Adhesive Preparation

1. Place lint and powder free latex gloves on when handling prepreg at all times. INITIALS JA

2. Record out time on NMIH label when removing any frozen material, If label is full, attach another label adjacent to the previous one. Weigh prepreg/adhesive rolls and jot number next to out time also fill out this info in table 1.

3. Allow 4 hours to thaw for large prepreg rolls. Return material to freezer immediately after cutting for your panel to minimize out time.

4. Record ambient temperature and humidity below. Temperature 73 % 4190 RK Humidity

#### Laminate Construction

1. Environment requirements for temperature and humidity for all steps of lay-up shall be maintained during the operation per the following:

Temperature =  $70 + -5^{\circ}F$ Hamidity = 40 - 55% INITIALS: J

2. Cut a piece of solid release film that is larger than the cut plies. Label the film with the panel ID along with the 0°, 45° and the 90° ply directional rosette on the edge of the film. Placement of rosette should be placed as seen below. Place the release film on top of the baseplate tool shown in Figure 3.



Figure 1. Rosette Location

3. Lay up plies of the material placed in the sequence listed in table 1. A vacuum debulk should always be performed after the 1st ply and at 5 ply intervals thereafter. After final debulk, repeat process for the second face sheet.

NITIALS: 3

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Ply #	Ply orientation (degrees)	Initial	13/13/2012
1	45	IN PT VE	( <del>x</del> .)
Debulk 5 minutes	1:30 1:40		1
2	-45	JN PT DB	i i i
3	0	JN PT JB	2
4	0	JN OT JB	
5	45	JN PT JB	
6	-45	TN DI JB	
Debulk 5 minutes	3.35 3.30	Per l'	1
7	90	JN PT JB	N
8	90	VUDT TB	
9	45	TUPT TR	22
10	-45	TUPT TB	
11	0	TNA TIZ	f.
Debuik 5 minutes	3'55 4:05	Je in up	
12	0	TO OT TR	1 10 20
13	45	TU OT TR 4	1500 8:301 121
14	90	PTTR	AM AM
15	45	TILDE TO	
16	0	TAL DT TIP	)
Debulk 5 minutes	9'25 5:35	5/0 F/ JL	1
17	0	TO DT TB	
18	-45	TN OT TR	
19	45	W PT TO	1 4
20	90 .	W PT TR	1
21	90	TUOTO	7 70
Debulk 5 minutes	10:04 10:20	101110	10
22	-45	TH PT TR	(
23	45	TU PT TR	/
24	0 .	IN DT TA	/
25	0 0	TNPT TH	1
26	-45	WPT JR	1
27	45	WPT TB	/



## Lay-Up & Bagging

## Bagging Sequence for Cure:

#### List of materials

- Tool aluminum, steel, Invar, composite (tool plates must be release coated or film covered)
- 2. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- s. Silicone/Rubber Edge Dams Thicker than faminate
- 4. Laminate
- 5. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- Caul plate aluminum, steel, invar, silicone rubber sheet (metal caul plates must be release coated or wrapped)
- 7. 2.2 psy polyester breather 1 or more
- Vacuum bag
- 9. Vacuum sealant
- Glass yarn string (alternatively or additionally breather may wrap over top of dam to contact edge)



#### Figure 3. Lay Up

1. Follow Figure 3 as a guide to panel lay up materials and layer sequence. Ensure curing plate has been solvent wiped to remove potential contaminants using MEK or acetone and clean lint free wipes. Wipe in a linear motion to prevent recontamination. INITIALS:

2. Install thermocouple to monitor the temperature of the part during cure. Bag part per Figure 3. Before bagging an EM40 engineer must check and sign off.

INITIALS: JP EM40 ENGINEER INTIALS:

3. Encompass lay up in vacuum bag in preparation for cure cycle. Pull vacuum at 25 inHg minimum. Leak check vacuum bag by disconnecting the vacuum line and installing a vacuum gauge. Ensure that the leak rate does not exceed 1.0 inHg after five minutes. If leak is detected completely replace vacuum bag and repeat process.

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4. Keep track of which thermocouple wire number is assigned to this panel during the cure by noting here:  $\frac{4}{4} - \frac{7}{50} L = 5 - P_{A} + 4$ 

5. Cure times and temperature shall be recorded using the autoclave data recorder for traceability. Print the recorded cure cycle profile and attach it to the Shop Traveler. Cure the panel using the autoclave per the following cure cycle:

- 75° to 350° @ 3°/min ~= 1 hour 30 min
- 350° hold ~= 2 hour 0 min
- 350° to 75° @ 5°/min ~= 60 min

## Pathfinder Panel Cure Cycle

Autoclave cure at 90 - 100 psi

## TC356 TOUGHENED EPOXY RESIN SYSTEM: Cure cycle



6. Remove all sharp edges from the as-cured panels using a file, rasp, or abrasive paper. Mark with panel identification, core ribbon direction, 0° orientation, 1.0" from the edge of the panel using a paint pen.

7. Record all anomalies or process deviations below and coordinate with EM40 Lead Engineer:

DATE: 12/17/12 INITIALS: P.T.

8. Deliver cured panel to EM20 for NDE inspection. Attach results of inspection to the end of this Work DATE:  $\frac{12}{12}$  INITIALS:  $\frac{312}{12}$ 



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9. Provide the results of the NDE inspection to the lead EM40 engineer.
DATE:\_\_\_\_\_\_ INITIALS:\_\_\_\_\_

10. After NDE, use the template to drill center holes (See attached drawing) and drill only two .5162-inch holes that will be required on one end at each corner for hanging the panels DATE: 1/15/1/3 INITIALS: JN GB

12. Provide a copy of the fabrication traveler to EV32, DATE: ///6/13 INITIALS: JW

13. Provide cured panel to EV32 DATE:\_\_\_\_\_\_INITIALS:\_\_\_\_\_


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Title: Pyroshock Pathfinder Work order aumber: 0320 Panel ID: 0320A005 0320 = Work Order Number I = IM7 Prepreg material fiber type 005 = panel number

Panel Dimensions: 36" x 72", 38 plies Panel Materials: JM7 12K, 150gsm/TC350, 24"

#### NOTES:

- Only materials listed in the applicable OWIs are permitted in the work area to aid in the prevention of contamination. Materials containing silicones and tools used with those materials are prohibited in the work areas.

- Vacuum bag material shall be verified to have no visible contamination prior to installation onto test panel for curing with an inspection distance of 6-18 inches using adequate shop lighting.

- For metallic support hardware, wipe down using lint free clean wiping cloths and Acetone or Methyl Bthyl Ketone (MEK) to remove any potential contamination that could be introduced into the processing.

Identity of test panels shall be maintained throughout processing, photography, and testing.

- If any anomalies occur during processing of this panel contact the NASA/EM40 Lead Engineer immediately and document the occurrence per EM40-OWI-37.

- All Kraft paper used through all processing steps will be of the acid-free type.

Table 1. Process and Material Identification Table.

Material	Identifying Numbers	Date Used	Time Out of Freezer	Time Into Freezer	Initials
IM7/TC350	TCAC 23423 IM7 12K 150 pm/173 34± 246 ResinContent Rell's 12, 13	12-18-12 # 12-19-12			P.T. J.N

Material	Identifying Numbers	Within Shelflife (Y/N)	Initials
Airweave	70300/0252	Y	P.T. J.N
Sealant Tape	Lot# 106 20/2	Y	P.T. J.N
Release Film	Asoon Vielet	Y	P.T. JA
Peel Ply (striped)	Nowe Used	Y	PT. J.W)
Vacuum Bag	10310299	Y	P.T. J.N

Process	Date	Time	Initials
Part was bagged	12-19-12	1:00 Am.	P.T. J.N.
Part was placed in autoclave	12-20-12	6:00 nm	J.N



Version:

1.0

#### Prepreg/Adhesive Preparation

1. Place lint and powder free latex gloves on when handling prepreg at all times. INITIALS <u>6.7</u>.

2. Record out time on NMIH label when removing any frozen material, If label is full, attach another label adjacent to the previous one. Weigh prepreg/adhesive rolls and jot number next to out time also fill out this info in table 1.

3. Allow 4 hours to thaw for large prepreg rolls. Return material to freezer immediately after cutting for your panel to minimize out time.

4. Record ambient temperature and humidity below. Temperature 7/ Humidity 42

#### Laminate Construction

 Environment requirements for temperature and humidity for all steps of lay-up shall be maintained during the operation per the following:

Temperature = 70 + 1.5°F Humidity = 40 - 55% INITIALS: <u>*P.T.*</u>

2. Cut a piece of solid release film that is larger than the cut plies. Label the film with the panel ID along with the  $0^{\circ}$ ,  $45^{\circ}$  and the  $90^{\circ}$  ply directional rosette on the edge of the film. Placement of rosette should be placed as seen below. Place the release film on top of the baseplate tool shown in Figure 3.



Figure 1. Rosette Location

3. Lay up plies of the material placed in the sequence listed in table 1. A vacuum debulk should always be performed after the 1st ply and at 5 ply intervals thereafter. After final debulk, repeat process for the second face sheet.

INITIALS: P.T

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Phy#	Ply orientation (degrees)	Initial
1	45	PT
Debulk 5 minutes	1:00 DECOM	PT
2	-45	PTTR
3	0	PT TA
4	0	PT TA
5	45	PT. TA
6	-45	PTJA
Debulk 5 minutes	10:00 - 10:15	P.T. TR
7	90	PTJA
8	90	PTJA
9	45	PTJR
10	-45	PTTR
11	0	PTTR
Debulk 5 minutes	12:00 - 1:15	AT TR
12	0	AT TR
13	45	17 50
14	-45	DT TR
15	90	AT TO
16	90	01 70
Debulk 5 minutes	2:45 - 3:00	AT TA
17	45	AT 00
18	-45	PT PC
19	0	AT RO
20	0	AT AC
20	-45	DT AC
Debulk 5 minutes	211-1-415	AT RA
22	45	AT AC
23	90	PT AC
24	90	OT RC.
25	-45	PT DC
26	45	AT BC
Debulk 5 minutes	SiDom - 6 DOAM	AT AC
27	0	RTIB
28	0	AT. J.A
29	-45	PT. J.A
30	45	PT. JA
31	90	P.T. J.A
Debulk 5 minutes	9:15 - 10:05	P.T. J.B
32	90	PT. J.A.

#### Table 1. Lay-up Sequence and Debulk Locations.

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33	-45	PT. JN.
34	45	PT. TN
35	0	P.T. T.N
36	0	PT. JN
Debulk 5 minutes	10:55 - 11:15	PT. J.N
37	-45	P.T. J.N
38	45	PTJN



1.0

#### Lay-Up & Bagging

Bagging Sequence for Cure:

#### List of materials

- Tool aluminum, steel, Invar, composite (tool plates must be release coated or film covered)
- 2. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- 3. Silicone/Rubber Edge Dams Thicker than laminate
- 4. Laminate
- 5. Release coat or film Frekote 700NC or 770NC, FEP, TEDLAR
- Caul plaze aluminum, steel, Invar, silicone rubber sheet (metal caul plates must be release coated or wrapped)
- 7. 2.2 osy polyester breather 1 or more
- s. Vacuum bag
- 9. Vacuum sealant
- Glass yarn string (alternatively or additionally breather may wrap over top of dam to contact edge)



#### Figure 3. Lay Up

1. Follow Figure 3 as a guide to panel lay up materials and layer sequence. Ensure curing plate has been solvent wiped to remove potential contaminants using MEK or acetone and clean lint free wipes. Wipe in a linear motion to prevent recontamination. INITIALS: f.T, IP.

2. Install thermocouple to monitor the temperature of the part during cure. Bag part per Figure 3. Before bagging an EM40 engineer must check and sign off.

INITIALS: <u>P. T.</u> EM40 ENGINEER INTIALS:\_\_\_

3. Encompass lay up in vacuum bag in preparation for cure cycle. Pull vacuum at 25 inHg minimum. Leak check vacuum bag by disconnecting the vacuum line and installing a vacuum gauge. Ensure that the leak rate does not exceed 1.0 inHg after five minutes. If leak is detected completely replace vacuum bag and repeat process.



4. Keep track of which thermocouple wire number is assigned to this panel during the cure by noting here: # $4-7\omega L$ , #5-Pwrf

5. Cure times and temperature shall be recorded using the autoclave data recorder for traceability. Print the recorded cure cycle profile and attach it to the Shop Traveler. Cure the panel using the autoclave per the following cure cycle:

- 75° to 350° @ 3°/min ~= 1 hour 30 min
- 350° hold ~= 2 hour 0 min
- 350° to 75° @ 5°/min ~= 60 min

#### Pathfinder Panel Cure Cycle

Autoclave cure at 90 - 100 psi

#### TC350 TOLIGHENED EPOXY BESIN SYSTEM: Cure cycle



6. Remove all sharp edges from the as-cured panels using a file, rasp, or abrasive paper. Mark with panel identification, core ribbon direction,  $0^{\circ}$  orientation,  $1.0^{n}$  from the edge of the panel using a paint pen.

7. Record all anomalies or process deviations below and coordinate with EM40 Lead Engineer:

DATE: 12-20-12	INITIALS: <u>P.T</u>		
3. Deliver cured panel to Fraveller.	EM20 for NDE inspect	tion. Attach results of inspec	ation to the end of this Work

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_ (	<b>Composite Materials Subjected to Pyroshock Loa</b>	ding	

9. Provide the results of the NDE inspection to the lead EM40 engineer.
DATE:\_\_\_\_\_\_\_INITIALS:\_\_\_\_\_\_

10. After NDE, use the template to drill center holes (See attached drawing) and drill only two .5162-inch holes that will be required on one end at each corner for hanging the panels DATE: 2/13-/23-2 INITIALS:

11. Install/bond provided inserts (#1428SKS) into the center holes of the panel. The inserts shall be flush with the panel or one side. Please remove looking parts of the inserts DATE: 2/13D33 INITIALS: 510

12. Provide a copy of the fabrication traveler to EV32. DATE: 2/19/2013 INITIALS: TA

13. Provide cured panel to EV32 DATE: 2/15/2013 INITIALS: JN

Figure A27. Monolithic Composite Panels #1 - #5 Fabrication Work Order



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Title:

Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

112 01 775

### Print Form

EM40-FORM-005 Baseline Effective Date: 2/11/08

## EM40 CONTRACTOR SUPPORT WORK ORDER

Pyroshock Characterization Panel 11-18	3. WORK ORDER NUMBER: 3	32
4. REQUEST COMPANY / PROJECT: MSEC/EV:	32	
5. CUSTOMER CONTACT NAME:	6. CUSTOMER PHONE NUMBER:	
David Ordway	256-544-8087	
7. CUSTOMER CONTACT ADDRESS:	8. CUSTOMER CONTACT EMAIL	ADDRESS:
MSFC, Bldg 4600, Rm 2103	david.o.ordway@nasa.gov	
9. SUBMISSION DATE: Apr 15, 2013	10. ANTICIPATED NEED DATE:	Jun 28, 2013
11. TYPE OF WORK:	12. QUALITY ASSURANCE (QA)	COVERAGE:
Drop-down List DEVELOPMENT TEST	Drop-down List NON QUALI	TY SENSITIVE
<ol> <li>Following panel cure perform Pulse Ultrasor</li> </ol>	und and Flash Thermography NDE on the panel an	1 11 1. 5140. 1
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VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE



Title:

## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

Version:

1.0

#### DETAILED INSTRUCTIONS

EM40-FORM-005 EM40 Contractor Support Work Order is a work authorization document used to request support from Marshall Space Flight Center's Materials and Processes Laboratory to conduct manufacturing support related activities. The information provided in this document will be reviewed and approved by the responsible NASA EM40 Engineer and forwarded to the necessary support organizations. An estimated cost and completion date will be generated and reported back to the requesting customer prior to start of the work order.

Block: Entry Explanation:

- 1 Enter short title of the work requested to be performed
- 2 Enter page number and total page number
- 3 A work order number will be provided by the NASA M&P Engineer
- 4 Enter company / project name that is requesting work
- 5 Enter customer contact's name
- 6 Enter customer contact's phone number beginning with area code
- 7 Enter customer contact's address
- 8 Enter customer contact's email address
- 9 Enter the date Work Order was submitted to NASA
- 10 Enter the anticipated date that end item should be delivered to customer
- 11 Check the type of work to be performed:
- Flight / GSE = Flight rated or Government Supplied Equipment hardware Qualification Test = qualification test hardware Development = development test hardware
- Test / Equip. Check = testing of equipment associated with TPS activities
- 12 Check the type of Quality Assurance Desired:
  - QS = Quality Sensitive work will require a NASA QA audit of the Shop Traveller where Government Mandated Inspection Points will be assigned and approved by QA representatives upon completion.
    - NQS = Non Quality Sensitive work will only require Contractor Level Quality signoffs
- 13 Enter a detailed description of the work requested. Specifics should include but are not limited too. Type of material to be used (customer supplied materials must have an MSDS attached) Type of substrate material to be used and any special substrate preparations required Material thickness requirements and/or layup requirements Environmental setpoints required during processing Environmental setpoints required post processing Post processing duration required before handling and/or testing etc. If the above information is not known, the requesting customer may specify "per program parameters" if applicable (i.e. External Tank, Ares I Upper Stage)
- 14 Enter funding code information if applicable. Primarily used by NASA internal projects
- 15 Enter customer signature and date
- 16 NASA M&P Engineer will sign upon approval
- 17 Enter NASA Quality Assurance signature and date if work is deemed Quality Sensitive

EM40-FORM-005

## Figure A28. Composite Sandwich Panel #11-#18 Fabrication Work Order



Version:

1.0

#### Print Form

EM40-FORM-005 Baseline Effective Date: 2/11/08

## EM40 CONTRACTOR SUPPORT WORK ORDER

Pyroshock Characterization Melamine Panels 4. REQUEST COMPANY / PROJECT: MSEC/EV 5. CUSTOMER CONTACT NAME: David Ordway 7. CUSTOMER CONTACT ADDRESS:	3. WORK ORDER NUMBER: 382 V32
4. REQUEST COMPANY / PROJECT: MSEC/EY 5. CUSTOMER CONTACT NAME: David Ordway 7. CUSTOMER CONTACT ADDRESS:	V32
5. CUSTOMER CONTACT NAME: David Ordway 7. CUSTOMER CONTACT ADDRESS:	6. CLISTOMER PHONE NUMBER
David Ordway 7. CUSTOMER CONTACT ADDRESS:	COSTONEET FRANC HOMACK.
7. CUSTOMER CONTACT ADDRESS:	256-544-8087
	8. CUSTOMER CONTACT EMAIL ADDRESS:
MSFC, Bldg 4600, Rm 2103	david.o.ordway@nasa.gov
9. SUBMISSION DATE: 06/18/2014	10. ANTICIPATED NEED DATE: 07/30/14
11. TYPE OF WORK:	12. QUALITY ASSURANCE (QA) COVERAGE:
Drop-down List DEVELOPMENT TEST	Drop-down List NON QUALITY SENSITIVE
14. FUNDING CODE (if applicable):	
14. FUNDING CODE (if applicable): 15. CUSTOMER SIGNATURE / DATE:	
14. FUNDING CODE (if applicable): 15. CUSTOMER SIGNATURE / DATE: DAVID ORDWAY	Digital grand in Controckman Dir co U, and S Grand Camp, Sector D, and Mr. Credwind Celeman, 1997 2018 (20000000) Tablescharp Dear 21 (no. 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2
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14. FUNDING CODE (if applicable): 15. CUSTOMER SIGNATURE / DATE: DAVID ORDWAY 16. NASA M&P ENGINEER APPROVAL:	Digitally upwellig controckensar Boy Science and Science and Science and Science and And Decement, Second Science and Science
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## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

#### DETAILED INSTRUCTIONS

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Block: Entry Explanation:

- Enter short title of the work requested to be performed
- 2 Enter page number and total page number
- 3 A work order number will be provided by the NASA M&P Engineer
- 4 Enter company / project name that is requesting work
- 5 Enter customer contact's name
- 6 Enter customer contact's phone number beginning with area code
- 7 Enter customer contact's address
- 8 Enter customer contact's email address
- 9 Enter the date Work Order was submitted to NASA
- 10 Enter the anticipated date that end item should be delivered to customer
- 11 Check the type of work to be performed:
- Flight / GSÉ = Flight rated or Government Supplied Equipment hardware Qualification Test = qualification test hardware Development = development test hardware
- Test / Equip. Check = testing of equipment associated with TPS activities
- 12 Check the type of Quality Assurance Desired:
  - QS = Quality Sensitive work will require a NASA QA audit of the Shop Traveller where Government Mandated Inspection Points will be assigned and approved by QA representatives upon completion.
    - NQS = Non Quality Sensitive work will only require Contractor Level Quality signoffs
- 13 Enter a detailed description of the work requested. Specifics should include but are not limited too. Type of material to be used (customer supplied materials must have an MSDS attached) Type of substrate material to be used and any special substrate preparations required Material thickness requirements and/or layup requirements Environmental setpoints required during processing Environmental setpoints required post processing Post processing duration required before handling and/or testing etc. If the above information is not known, the requesting customer may specify "per program parameters" if applicable (i.e. External Tank, Ares I Upper Stage)
- 14 Enter funding code information if applicable. Primarily used by NASA internal projects
- 15 Enter customer signature and date
- 16 NASA M&P Engineer will sign upon approval
- 17 Enter NASA Quality Assurance signature and date if work is deemed Quality Sensitive

EM40-FORM-005

Figure A29. MAF Panel Fabrication Work Order

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cument #: SC-RP--00783

Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading



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Figure A30. Composite Sandwich Panel Fabrication – Pictorial Presentation



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## **A3.1** Post-Panel Fabrication NDE

Two methodologies are commonly used for NDE of composites, phased array ultrasound (PAUT) and flash infrared thermography. Both of these methodologies were used for the IM7/R913 composite pathfinder panels. The pathfinder composite panels were 0.20 inch thick, which is approaching the maximum thickness for infrared thermography inspection. It was determined from inspection of the composite pathfinder panels the surface texture and overall panel thickness reduced the detection capability of infrared thermography. Based on the test results only the phased array ultrasound inspection methodology was used for the task baseline IM7/TC350 composite panel NDE, which was not limited in resolution by the panel surface texture or thickness. Figure A31 shows the IR thermography results and Figure A32 documents the phased array ultrasound results for the composite pathfinder panels.

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**Revision** A

# Thermographic Inspection Report Work Order 2012-0298

## **Prepared For**

James Walker NASA MSFC James.L.Walker@nasa.gov (256) 961-1784

## Prepared By

Scott Ragasa UAH RSESC Joseph.S.Ragasa@nasa.gov (256) 544-3935

## **Specimen Information**

Project Serial Number Surface Preparation Special Handling NESC Pyroshock Pathfinder None None

## **Inspection Equipment**

Infrared Camera FLIR SC6000 Lens 25 mm Heating Method Flash Lamps Hood Configuration Small FOV

## **Inspection Settings**

Capture Software	EchoTherm 8
Image Size	640 x 512
<b>Capture Frequency</b>	10 Hz
<b>Capture Duration</b>	27.6 sec
Flash Duration	N/A
Flash Delay	0 msec
Flash Frame	10
TSR Skip Frames	1

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**Revision A** 

#### Overview

The panel was subdivided into four quadrants according to Figure 1.

Quadrant II	Quadrant I
Quadrant III	Quadrant IV

Figure 1



**Composite Materials Subjected to Pyroshock Loading** 

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The thickness of the panel is approaching the maximum that can be inspected by flash thermography. A reduced acquisition rate of 10 frames per second was used to achieve the best compromise of detectability and interrogation depth.

Figure 2 shows the logarithmic time versus temperature curve over a nominal area of the panel. Note the slight upward trend when the panel back wall is reached.

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Two indications, approximately 0.25" by 0.25", were found in inspection location D3 and denoted by the red circles. Time-temperature cursors, shown in red and green, were placed on each indication and measured the average intensity value of the local 3 by 3 pixel area. A blue reference time-temperature cursor was placed over a nominal area for comparison. Plotting the data from the two indications and the reference point shows that both indications deviate from the behavior of nominal areas of the panel.

In addition to infrared thermography, phased array ultrasound (PAUT) was used to inspection the panel. PAUT did not detect any anomalies at grid location D3, and as a result, it is believed the indications present in the thermographic data are the result of a surface condition.

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#### Comments

The surface texture of the panel also influenced the acquired data. As shown in Figure 3 the raw, first derivative, and second derivative images (a, b, and c, respectively) exhibit a mottled texture in the infrared images.



Figure 3a

Figure 3b

Figure 3c

The combination of infrared thermography and phased array ultrasound nondestructive inspection techniques provided a thorough interrogation of the panel. The surface texture and overall panel thickness reduced the detection capability of infrared thermography.

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# Appendix

# **Overview and Full-Size Quadrant Mosaics**

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Quadrant IV

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Raw Data - Quadrant IV



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First Derivative – Overview

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First Derivative - Quadrant IV



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Second Derivative - Overview



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Second Derivative - Quadrant II



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Second	Derivative – Quadrant III

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Second Derivative - Quadrant IV



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Figure A31. Pathfinder Composite Flash Infrared Thermography Inspection Results

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## **Ultrasonic Inspection Report**

# EV32 Pyroshock Pathfinder Panel Work Order 2012-0298

## 18 July 2012

### Prepared By

Matthew R. McDougal EM20 Nondestructive Evaluation Team NASA Marshall Space Flight Center (256) 544-7783 matthew.mcdougal@nasa.gov

#### Specimen Information

36" x 72" composite panel

Description Part Numbers

120298001

#### Inspection Equipment

Instrument Olympus TomoScan Focus LT, SN FLT-1190 Software Olympus TomoView 2.9R13 Scanner Amdata Catamaran Probe Olympus 2.25L64-A2 MHz Phased Array, SN G0120 Wedge Olympus SA2-0L-IHC

#### Inspection Settings

Mode Frequency Law Configuration Acquisition Range Filter Gain Compression Scanning Rate Scan Resolution Couplant Orientation

Notes

Pulse Echo 2.25 MHz 0° linear scan, 8 aperture, approx 0.1" focus 16.8 µsec None 15 dB 5 samples 0.6 in./sec 0.0295" x 0.0394" Submerged in water Scanned from back surface in 3 columns with edge with writing at the bottom. Images oriented to front view. None

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Panel Overview

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Photo of panel, oriented to match other imagery

Panel Overview

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Overview composite image of data from all three scans.

Ten indications were noted on this panel. Seven of the ten indications were corroborated by being seen in 2 separate scans. Sizes vary and most of the indications appear to be approximately midway through the panel thickness. There are also several indeterminate areas with scattered small reflections. Notably, none of the indications appear to correlate with indentions and markings visible on the rear surface of the panel.

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Center column scan showing location of 10 numbered indications.



Indication Details

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## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

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Indication	X (inches)	Y (inches)	Width (inches)	Height (inches)	Depth (% thick)
1	27.8	5.4	0.68	0.51	52%
2	46.4	6.1	0.26	0.24	79%
3	34.9	0.7	0.15	0.36	56%
4	29.8	7.5	0.24	0.47	60%
5	44.6	17.9	0.24	0.17	74%
6	50.6	28.6	1.27	2.33	63%
7	49.1	27.9	0.24	0.35	74%
8	39.0	33.4	0.48	0.79	54%
9	27.8	31.8	0.20	0.20	80%
10	23.0	25.6	0.29	0.55	59%

Data about the indications are summarized in the above table. The zero point for measurements is approximately 0.5" inset from both edges at the top right corner of the panel. X is measured from the right edge of the panel and Y is measured from the top edge of the panel. Width is in the X dimension and height is in the Y dimension. Depth is scaled such that 0% would be the top surface, 100% would be the bottom surface. All of these measurements are very rough. Later, all of the indications were reconfirmed by hand scan and more accurate locations marked directly on the panel.



Image of indications as marked on panel surface.

Figure A32. Pathfinder Composite Phased Array Ultrasound Inspection Results

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Figure A33 illustrates typical ultrasound inspection data of the monolithic IM7/TC350 composite panels and the high-level assembly quality of the panels (no significant indications were found in any of the TC350 composite panels).

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# Ultrasonic Inspection Report

# **Pyroshock Panels** Work Order 2012-0620

## 14 December 2012

### Prepared By

Matthew R. McDougal EM20 Nondestructive Evaluation Team NASA Marshall Space Flight Center (256) 544-7783 matthew.mcdougal@nasa.gov

### Specimen Information

Description	~ 36" x 72" composite panels, 0.2" thick, qty. 2
Part Numbers	0320A001 and 0320A002

### Inspection Equipment

Instrument Olympus Tomoscan Focus LT, SN FLT-1190 Scanner Amdata Catamaran Probe Olympus 2.25L64-A2 Phased Array, SN G0120 Wedge Olympus SA2-OL-IHC

### Inspection Settings

Mode Frequency Law Configuration Acquisition Range Filter Compression Scanning Rate 0.7 in./sec Orientation

Notes

Pulse Echo 2.25 MHz 0° linear scan, 8 aperture, approx. 0.1" focus 16.8 µsec None Gain 13.5 dB 5 samples Scan Resolution 0.0295" x 0.0394" Couplant Submerged in water Scanned in 3 columns, min. 5" overlap. Panel text at bottom left. None

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Gated for front surface

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Gated for through-thickness.

One tiny indication.

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Gated for back surface.

No indications noted. Patterns are due to air bubbles trapped under panel during scan.

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Gated for front surface.

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Gated for through-thickness.

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Gated for back surface.

No indications noted. Spots are from air bubbles trapped under panel during scan.

## Figure A33. Ultrasound Inspection Results of Monolithic Test Panel #1 and #2

Phased array ultrasound (also referred herein as pulse echo ultrasound) was also used for NDE of the composite sandwich panels. The technique used was entirely acceptable for the through thickness of the composite face sheets and the bond line between the face sheets and the fill core material. Results from the pulse echo ultrasound for composite sandwich panels #11 through #18 are documented in Figure A34. Ultrasound inspection, however, is not a suitable NDE method for evaluating flaws in the foam filler core material. A study was undertaken to evaluate an acceptable NDE methodology for resolving a flaw (crack) in the ROHACELL<sup>®</sup> foam. Two methods were evaluated; digital radiography (DR) and computed tomography (CT). The results of the study are documented in Figure A35, which show only the CT method was able to detect flaws in the foam filler material.



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## Ultrasonic Inspection Report

# Pyroshock Panels Work Order 2013-0397

## 30 May 2013

### Prepared By

Matthew R. McDougal EM20 Nondestructive Evaluation Team NASA Marshall Space Flight Center (256) 544-7783 matthew.mcdougal@nasa.gov

#### Specimen Information

Description Part Numbers  $^{\sim}$  36" x 72" composite sandwich panel, 0.12" facesheets 0332A011

### Inspection Equipment

Instrument Scanner Probe Wedge Olympus Tomoscan Focus LT, SN FLT-1190 Amdata Catamaran Olympus 2.25L64-A2 Phased Array, SN G0120 Olympus SA2-0L-IHC

#### Inspection Settings

Mode Frequency Law Configuration Acquisition Range Filter Gain Compression Scanning Rate Scan Resolution Couplant Orientation

Notes

Pulse Echo 2.25 MHz 0° linear scan, 8 aperture, approx. 0.1" focus 16.8 µsec None 20 dB 5 samples 0.7 in./sec 0.0295" x 0.0394" Submerged in water Scanned in 2-3 columns, 4-6" overlap. Panel text at bottom left. None Panel 0332A011 Front

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Front side, gated for facesheet thickness.

No indications noted.

Panel 0332A011 Front

Page 3 of 5



Front side, gated for bondline.

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Panel 0332A011 Back

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Back side, gated for facesheet thickness.

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Panel 0332A011 Back

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Back side, gated for bondline.



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# Ultrasonic Inspection Report

# Pyroshock Panels Work Order 2013-0397, Part II

## 14 June 2013

## Prepared By

Matthew R. McDougal EM20 Nondestructive Evaluation Team NASA Marshall Space Flight Center (256) 544-7783 matthew.mcdougal@nasa.gov

Scott Ragasa University of Alabama in Huntsville (256) 544-3935 joseph.s.ragasa@nasa.gov

### Specimen Information

Description Part Numbers

~ 36" x 72" composite sandwich panel, 0.12" facesheets 0332A014

### Inspection Equipment

Instrument Scanner Probe Wedge Olympus Tomoscan Focus LT, SN FLT-1190 Amdata Catamaran Olympus 2.25L64-A2 Phased Array, SN G0120 Olympus SA2-0L-IHC

#### Inspection Settings

Mode Frequency Law Configuration Acquisition Range Filter Gain Compression Scanning Rate Scan Resolution Couplant Orientation Notes Pulse Echo 2.25 MHz 0° linear scan, 8 aperture, approx. 0.1" focus 16.8 µsec None 20 dB 5 samples 0.7 in./sec 0.0295" x 0.0394" Submerged in water Scanned in 2 columns, 4-6" overlap. Panel text at bottom left. None

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Panel 0332A014 Front

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Front side, gated for facesheet thickness.

No indications noted.

Panel 0332A014 Front

Page 3 of 5



Front side, gated for bondline.

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Panel 0332A014 Back

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Back side, gated for facesheet thickness.

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Back side, gated for bondline.



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# Ultrasonic Inspection Report

# **Pyroshock Panels** Work Order 2013-0397, Part III

## 9 July 2013

## Prepared By

Matthew R. McDougal EM20 Nondestructive Evaluation Team NASA Marshall Space Flight Center (256) 544-7783 matthew.mcdougal@nasa.gov

Scott Ragasa University of Alabama in Huntsville (256) 544-3935 joseph.s.ragasa@nasa.gov

#### Specimen Information

Description	~ 36" x 72" composite sandwich panels, qty. 6
Part Numbers	0332A012, 0332A013, 0332A015, 0332A016, 0332A017, 0332A018

#### Inspection Equipment

Instrument	Olympus Tomoscan Focus LT, SN FLT-1190
Scanner	Amdata Catamaran
Probe	Olympus 2.25L64-A2 Phased Array, SN G0120
Wedge	Olympus SA2-0L-IHC

#### Inspection Settings

Mode Frequency Law Configuration Acquisition Range Filter Gain Compression Scanning Rate 0.7 in./sec Scan Resolution 0.0295" x 0.0394" Orientation Notes

Pulse Echo 2.25 MHz 0° linear scan, 8 aperture, approx. 0.1" focus 16.8 µsec None 20 dB 5 samples Couplant Submerged in water Scanned in 2 columns, 4-6" overlap. Panel text at bottom left. None

Panel 0332A012 Front

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Front side, gated for facesheet thickness.

No indications noted.

Panel 0332A012 Front

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Front side, gated for bondline.

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Back side, gated for facesheet thickness.

No indications noted.

Panel 0332A012 Back

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Back side, gated for bondline.

Panel 0332A013 Front

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Front side, gated for facesheet thickness.

No indications noted. Patterns are due to surface features and wrinkles.

Panel 0332A013 Front

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Front side, gated for bondline.

No indications noted. Patterns are due to surface features and wrinkles.

Panel 0332A013 Back

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Back side, gated for facesheet thickness.

No indications noted.

Panel 0332A013 Back

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Back side, gated for bondline.

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Front side, gated for facesheet thickness.

No indications noted.

Panel 0332A015 Front

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Front side, gated for bondline.

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Back side, gated for facesheet thickness.

No indications noted.

Panel 0332A015 Back

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Back side, gated for bondline.

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Front side, gated for facesheet thickness.

No indications noted.

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Front side, gated for bondline.

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Back side, gated for facesheet thickness.

No indications noted.

Panel 0332A016 Back

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Back side, gated for bondline.

Panel 0332A017 Front

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Front side, gated for facesheet thickness.

No indications noted. Patterns are due to surface features and wrinkles.

Panel 0332A017 Front

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Front side, gated for bondline.

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Back side, gated for facesheet thickness.

No indications noted.

Panel 0332A017 Back

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Back side, gated for bondline.

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Panel 0332A018 Front

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Front side, gated for facesheet thickness.

No indications noted.

Panel 0332A018 Front

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Front side, gated for bondline.
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Back side, gated for facesheet thickness.



Panel 0332A018 Back

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Back side, gated for bondline.

No indications noted.

Figure A34. NDE Ultrasonic Inspection Results of Composite Sandwich Panels #11 - #18.



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1.0

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### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

### Data Sheet for MSFC ACTIS Scanning

Date:6/4/2013	Work order #:2013-V-0397	

Notes: Pyroshock Char-Comp Materials. Perform DR on test sample to attempt to resolve crack in foam.

Record system verification checks (date/time, otherwise n/a):				
	1	2	3	
Offset:	9/4/2013   0813	9/4/2013 0822	1.0	
Gain:	9/4/2013 0814	9/4/2013 0823		
Find Geometry:	n/a	n/a		



Foam sample on CT table.

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE http://em20.msfc.nasa.gov/oi.htm

EM20-NDE-FM-002 09-21-2009

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Sample on table. Looking CT 180 degrees to CT 0 degrees.

Slice name	<u>Slice</u> <u>Height</u>	Indications/Notes	Thumbnail
A0001	DR	Start = 440; end = 80; field width = 400mm; aperture width = 1mm; linatron pulses =2	
A0002	DR	Start = 440; end = 80; field width = 400mm; aperture width = 2mm; linatron pulses = 2	
A0003	DR	Start = 440; end = 80; field width = 400mm; aperture width = 1mm; linatron pulses = 1	
A0004	DR	Start = 440; end = 80; field width = 400mm; aperture width = 2mm; linatron pulses = 1	
A0005	DR	Start = 440; end = 80; field width = 400mm;	

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE http://em20.msfc.nasa.gov/oi.htm

EM20-NDE-FM-002 09-21-2009



<u>Slice</u> <u>name</u>	<u>Slice</u> <u>Height</u>	Indications/Notes	<u>Thumbnail</u>
		aperture width = 2mm; linatron pulses =1; set oversampling to 3.0	
A0006	315	Test slice. Crack visible.	

Supplemental data: Slice A0001



Supplemental data: Slice A0002

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE http://em20.msfc.nasa.gov/oi.htm

EM20-NDE-FM-002 09-21-2009

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Supplemental data: Slice A0003



Supplemental data: Slice A0004

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EM20-NDE-FM-002 09-21-2009

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Supplemental data: Slice A0005



Supplemental data: Slice A0006

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EM20-NDE-FM-002 09-21-2009

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Conclusion/summary: Five digital radiographs (DR) and one CT slice was collected in this study. The crack did not show in the DR's. It did show faintly in the CT slice. Use of the CT scanner in DR mode doesn't seem feasible in this case. A CD containing the collected CT images in jpeg format accompanies the hard copy of this report. All CT images are archived at the lab and remain available for subsequent analysis.

CHECK THE MASTER LIST – VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE http://em20.msfc.nasa.gov/oi.htm EM20-NDE-FM-002 09-21-2009 Page | 6

Figure A35. DR and CT Evaluation of Core Filler Material after Assembly

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## Appendix B. Pyroshock Test Reports

### **B1.** Pathfinder Tests

The test report documenting the test results from pathfinder test group, tests 1 through 3 is documented in the attachment below.



### NASA Engineering and Safety Center Technical Assessment Report

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Title:

### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812 October 9, 2012



Reply to Attn ol: ET40-12-022

TO:	EV32/David O. Ordway
FROM:	ET40/Timothy C. Driskill
SUBJECT:	Initial Tests for the Composite Materials Pyroshock Development Test, NESC-DEV-12-014

The aluminum and solid composite pathfinder panel test articles were tested in the ET40 Pyrotechnic Shock Facility, building 4619, room 170. Testing was completed on September 10, 2012. The test was run in accordance with Test and Checkout Procedure, (TCP) NESC-DEV-12-014. Two tests were run on the aluminum pathfinder panel and one test was run on the solid composite pathfinder panel. The accelerometer test setup is shown in appendix A of the TCP and in the photographs section of this report. No visual damage to the test articles was noted.

Please direct any questions or comments regarding this test to Mr. Craig Garrison at (256) 544-7197 or craig.garrison@nasa.gov.

Ac

Timothy C. Driskill Branch Chief Structural Dynamics Test Branch

Enclosure

cc: EE04L/MSFC: C105/Steven Gentz ES22/David Parsons ET01/File (w/o enclosure) ET40/Timothy Driskill

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# Photographs

Overall Setup, Test T01 Accelerometer Locations, Test T01 Side View, Test T01 Explosives Location, Test T01 Explosives Location, Post-test, Test T01 LSC Plate Close-up, Post-test, Test T01

Accelerometer Locations, Test T02 Side View, Test T02 Explosives Location, Test T02 Explosives Location, Post-test, Test T02 LSC Plate Close-up, Post-test, Test T02

Accelerometer Locations, Test T03 Side View, Test T03 Explosives Location, Test T03 Explosives Location, Post-test, Test T03 LSC Plate Close-up, Post-test, Test T03

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**Overall Setup, Test T01** 

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Accelerometer Locations, Test T01

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Side View, Test T01

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**Explosives Location, Test T01** 

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**Explosives Location, Post-Test, Test T01** 

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LSC Plate Close-up, Post-Test, Test T01

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Accelerometer Locations, Test T02

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Side View, Test T02

A STATE OF S	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: 1.0
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**Explosives Location, Test T02** 

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Explosives Location, Post-Test, Test T02

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LSC Plate Close-up, Post-test, Test T02

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Composite Materials Subjected to Pyroshock Loading				



Accelerometer Locations, Test T03

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: 1.0
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Side View, Test T03

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: 1.0
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**Explosives Location, Test T03** 

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**Explosives Location, Post-Test, Test T03** 

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LSC Plate Close-up, Post-Test, Test T03

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# **Test Data**

### Initial Tests for the Composite Materials Pyroshock Development Test

Accelerometer Location to Plot Channel Mapping

SRS Test T01 Test T02 Test T03

Time History Test T01 Test T02 Test T03

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# **Test Data**

Data		Data
Acquisition	Accel.	Plots
Channel	Location	Channel*
2	A1	1
3	A2	2
4	A3	3
5	A4	4
6	A5	5
7	A6	6
8	A7	7
10	A8	8
11	A9	9
12	A10	10
13	A11	11
14	A12	12
15	A13	13

\*Channels were renamed for automated data analysis

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# **Test Data**

## SRS Test T01

## Aluminum Pathfinder Panel 10 gpf, FLSC

The Spec. line for Test T01 is the Estimated Source Shock

Hz.	SRS g's
100	500
1750	8500
10k	8500

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# **Test Data**

### SRS Test T02

## Aluminum Pathfinder Panel 22 gpf, FLSC

The Spec. line for Test T02 is the Estimated Source Shock

Hz.	SRS g's
50	500
1750	13,000
10k	13,000

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# Test Data

### SRS Test T03

## Solid Composite Pathfinder Panel 10 gpf, FLSC

The Spec. line for Test T03 is the Estimated Source Shock

Hz.	SRS g's
100	500
1750	8500
10k	8500

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### **Test Data**

Time History Test T01

### Aluminum Pathfinder Panel 10 gpf, FLSC

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# Test Data

### Time History Test T02

### Aluminum Pathfinder Panel 22 gpf, FLSC

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## **Test Data**

#### Time History Test T03

### Solid Composite Pathfinder Panel 10 gpf, FLSC

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# **Test and Checkout Procedure**

# NESC-DEV-12-014

# "As Run"

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As Run Record Copy

NESC-DEV-12-014 8/3/2012

George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812

# TEST AND CHECK-OUT PROCEDURE

ET40 / VIBRATION, ACOUSTICS, AND SHOCK TEAM

# INITIAL TESTS FOR THE COMPOSITE MATERIALS PYROSHOCK DEVELOPMENT TEST

This Procedure Describes Safety Critical Operations



Title:

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**Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading** 

ET40 / V	ibration, Acoustics, and Shock T	eam	
Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
Pyroshock Development Test	Date: 8/3/2012	Page 1 of 11	

PREPARED BY: John Craig Garrison / ET40 Test Engineer

8/6/2012 Date

APPROVED BY

Kathy L. Owen / ET40 Deputy Branch Chief

Structural Dynamics Test Branch

APPROVED BY

8/6/12 Date

David Ordway / EV32 Aerospace Engineer, Pyrotechnics Structural & Mechanical Design Branch Test Requester

8/6/12 Date APPROVED BY: David Barsons

David Parsons / ES22 Structural Dynamics Mechanical, Thermal and Life Support Branch



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Title:

## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

ET40/V	ibration, Acoustics, and Shock T	eam	
Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
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### 1.0 <u>INTRODUCTION</u>

1.1 PURPOSE

The purpose of this procedure is to define the steps necessary to perform a pyrotechnic shock test in the Pyrotechnic Shock Facility in Building 4619 using pyrotechnic devices.

Test Article: <u>3'x6'x0.19 aluminum setup plate or 3'x6'x0.2" solid composite pathfinder</u> panel with LSC plate and LSC backing plate. Program: <u>NESC</u> Type of Test: <u>Pyrotechnic Shock Development Test</u> Test Purpose: <u>To capture the acceleration time history of initial test setup and</u> instrumentation checkout panels.

The Pyrotechnic Shock Facility is located in Rooms 170, 170A and 170B of Building 4619. Room 170A is designated as the Control Room. The area between Room 169 and 170 is used for storage of secondary pyrotechnic devices. Room 170B is used for storage of initiators. All detonation of pyrotechnic devices will be in Room 170.

1.2 SCOPE

This document contains the steps and/or references the procedure to conduct the test.

2.0 <u>SAFETY</u>

Follow all emergency and safety requirements specified in ET01-DYN-SHK-FOP-001.

2.1 <u>Responsibilities</u>

The Test Engineer will be responsible for all activities occurring in the hazardous test area and for the safety of personnel involved in the test activities. It is the responsibility of each individual in a test program to fully comply with the requirements of this document and to report any individual not complying. Failure to do so could lead to serious personnel injuries or death.

- 3.0 TEST REQUIREMENTS AND INFORMATION
- 3.1 DOCUMENTS
- 3.1.1 APPLICABLE DOCUMENTS

Test Requirements: Pyroshock Response Characterization of Composite Materials Test Plan NESC Task # TI-12-0783, 7/2/2012

Test Procedure: ET01-DYN-SHK-FOP-001 Pyrotechnic Shock Tests



NESC-RP-12-00783

## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

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Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
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97M00201 SET UP PLATE, COMPOSITE TEST PANEL PATHFINDER 97M00201 MOD SET UP PLATE, COMPOSITE TEST PANEL PATHFINDER 97M00202 LSC BACKING PLATE, COMPOSITE TEST PANEL PATHFINDER 97M00203\* LSC PLATE, COMPOSITE TEST PANEL PATHFINDER 97M00204\* LSC SHIM, COMPOSITE TEST PANEL PATHFINDER 97M00205 10 GR/FT LSC, COMPOSITE TEST PANEL PATHFINDER Note: \* Add "-mod" to the Dawing Number for al-tested configuration C.D. 9/20/20/2

### 3.1.2 REFERENCED DOCUMENTS

ET01-DYN-OWI-001 Documentation Control

- ET01-DYN-OWI-002 Test Operation Procedure Preparation and Change Control
- 3.2 TEST INFORMATION
- 3.2.1 The instrumentation locations are given in the drawings listed in the applicable documents and appendix A for the test.
- 3.2.2 Pyrotechnic shock tests may be performed on the test article in the order and configuration directed by the test requester.
- 3.2.3 The shock test will be performed on a room temperature test article.
- 3.3 TEST REQUIREMENTS
- 3.3.1 The Test Engineer will be in charge of all test preparations and activities.
- 3.3.2 All activities will be coordinated with the Test Engineer.
- 3.3.3 All changes to the procedure will be coordinated with the Test Engineer.
- 3.3.4 The development test articles will be tested with pyrotechnic shock test runs as directed by the test requester. The test article information will be recorded in this TCP.
- 4.0 <u>TEST DATA</u>
  - a. The test data includes a time history of the real time shock recorded over a 50 millisecond or longer interval and the units are g's peak versus time.
  - b. The second plot is a Shock Response Spectrum (SRS) using 5% damping and a 1/6 octave shock spectrum analyzer. The SRS is computed over the frequency band from 50 to 10,000 Hertz. The SRS units are g's versus frequency.
  - c. The data will be acquired on a Nicolet BE256LE data acquisition system and the SRS analysis will be performed using a personal computer and the Shock Analysis Tool Analysis Software.
  - d. Sample rate of 1 million samples per second will be used for response from the accelerometers.



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4 corner holes with

ating D-rings)

## **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

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#### 5.0 TEST SETUP

#### 5.1 TEST ARTICLE AND SHOCK PLATE SETUP

- a. The test setup is shown in Appendix A.
- b. Suspend the shock plate from ceiling using straps or cables and shackles.
- c. Suspend 1 accelerometer near the plate. Connect to data system for recording. (A13)
  - d. Instrument shock plate. Each accelerometer's torque will be to 30±5 in.-lb.
- Torque wrench: M659927 Torque value: 35 in-16. Due: 11-21-2012
- LSC plate and LSC backer plate to Test Panel. Each  $\frac{1}{2}$  bolt's torque will be to  $55 \frac{1}{5} \frac{1}{1}$  bolt's torque wrench:  $\frac{10}{10} \frac{59925}{10}$  Torque value:  $\frac{55}{10} \frac{1}{10} \frac{1}{10}$ e. Due: 11/21/2012 28 ft-16.

#### 6.0 TEST OPERATION

#### INITIAL TESTS FOR THE COMPOSITE MATERIALS PYROSHOCK DEV. TEST 6.1

a. Record and verify the test information below and in appendix B.

Test No.: 1. Date: 8/10/2012\_ Test Article Desc.: Aluminum Plate, 3'x6'x0.19" Shock Source LSC Core Load: 10 GR/FT Explosive Material: RDX Sheath: Al Actual Length Used: 48.5

Measure the overall width of the FLSC: 0.130" + 0.137" Measure the width of the FLSC inside the apex (inverted chevron): 0.094"

- b. Verify that the shock plate is ready for testing per section 5.1.
- c. At the start of each test day, complete ET01-DYN-SHK-FOP-001, section 6.
- d. Photograph the locations and orientations of all accelerometers.
- e. Perform the test per sections 7, 8, and 9 of ET01-DYN-SHK-FOP-001.
- Photograph the test setup after the test. Photograph and document any post-test f.
- visually inspected observations under this test number in appendix B.
- f. Verify that the test run has been completed.

VQCA 8/10/2012

#### 6.2 INITIAL TESTS FOR THE COMPOSITE MATERIALS PYROSHOCK DEV. TEST

a. Record and verify the test information below and in appendix B.

Test No.: 2 Date: 8/16/2012 Test Article Desc.: Aluminum Plate, 3'x6'x0.19" Shock Source LSC Core Load: 22 GR/FT Explosive Material: CH-6 Sheath: Al Actual Length Used: 45" Measure the overall width of the FLSC: 0. 178"

### Measure the width of the FLSC inside the apex (inverted chevron): 0.120"

- b. Verify that the shock plate is ready for testing per section 5.1.
- c. At the start of each test day, complete ET01-DYN-SHK-FOP-001, section 6.
- d. Photograph the locations and orientations of all accelerometers.
- e. Perform the test per sections 7, 8, and 9 of ET01-DYN-SHK-FOP-001.



12-00783

### Title: **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

1.0

ET40 / V	ibration, Acoustics, and Shock T	eam	
Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
Pyroshock Development Test	Date: 8/3/2012	Page 5 of 11	

Photograph the test setup after the test. Photograph and document any post-test f. visually inspected observations under this test number in appendix B.

Verify that the test run has been completed.

1 gc & 8/16/2012

6.3 INITIAL TESTS FOR THE COMPOSITE MATERIALS PYROSHOCK DEV. TEST

a. Record and verify the test information below and in appendix B.

Test No.: 3 Date: 9/10/2012 Test Article Desc.: Composite Panel, 3'x6'x0.2" Shock Source LSC Core Load: 10 GR/FT Explosive Material: RDX Sheath: Al Actual Length Used: 48" Measure the overall width of the FLSC: 0.130" + 0.132"

Measure the width of the FLSC inside the apex (inverted chevron): 0.094"

- b. Verify that the shock plate is ready for testing per section 5.1.
- c. At the start of each test day, complete ET01-DYN-SHK-FOP-001, section 6.
- d. Photograph the locations and orientations of all accelerometers.
- e. Perform the test per sections 7, 8, and 9 of ET01-DYN-SHK-FOP-001.
- Photograph the test setup after the test. Photograph and document any post-test f.
- visually inspected observations under this test number in appendix B.
- Verify that the test run has been completed. g.

#### 7.0 RECORDS

The test report for this test will control and include the following records: a. This "AS RUN" TCP.

b. The test data and the equipment list.

The test report is controlled by ET01-DYN-OWI-001, Documentation Control. However, due to the ITAR designation for the test results, the test report and data will be securely controlled. The test report will be available no later than 30 days after test completion. The Test Requirements will not be included in this TCP or in the report, but a copy may be filed with the report for future reference.

#### 8.0 TOOLS, EQUIPMENT, AND MATERIALS

The equipment used during this test will be listed in a table as part of the test report. The list will include test equipment calibration due dates.

#### 9.0 PERSONNEL TRAINING AND CERTIFICATION

Personnel certified as Propellant and Explosive Handler are required to conduct this test.



1.0

# **Empirical Model Development for Predicting Shock Response on**

ET40 / V	lbration, Acoustics, and Shock T	eam
Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:
Pyroshock Development Test	Date: 8/3/2012	Page 6 of 11
POS	1-TEST VERIFICATIO	N

9/10/2012 Date In Ging Danis Test Engineer / ET40

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Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading			

ET40 / V	ibration, Acoustics, and Shock T	eam	
Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
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# APPENDIX A

TEST SETUP



1.0

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## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

Test Article Panel:

Supports:

ET40 / V	ibration, Acoustics, and Shock T	eam	
Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
Pyroshock Development Test	Date: 8/3/2012	Page 8 of 11	

3.00" .... 9 0 • 0 • A1 A3 A5 A7 A9 A11 ø 0 0 0 • 0 0 A4 A6 A8 A2 A10 A12 0 0 ٥ . ٥ ۰ 0 - Linear Shape Charge Blasting Cap 0 • • 0 0 0 10 0 0 . 0 0 ..... 0 .... 0 0 0 • 0 0 0

Initial Tests for the Composite Materials Pyroshock Development Test

Straps and Shackles

Aluminum or Composite, Vertical Position

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: <b>1.0</b>
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Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
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# APPENDIX B

TEST DATA SHEET



Title:

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### **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

ET40 / Vibration, Acoustics, and Shock Team NESC-DEV-12-014 Initial Tests for the Composite Materials **Revision:** Page 10 of 11 Pyroshock Development Test Date: 8/3/2012

### TEST DATA SHEET

Test No.: 1 Date: 8/10/2012 Test Article Desc.: Aluminum Plate, 3'x6'x0.19" Test Article Configuration: Hanging Test Article Drawing #: 97M00201 Material: Aluminum 5052 S/N: Pathfinder Test Article Drawing #: 97M00202 Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00203\* Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00204\* Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00205 Shock Source LSC L/N: none LSC Core Load: 10 GR/FT Explosive Material: RDX Sheath: Aluminum Actual Length Used: 48.5 Accelerometer MFG: PCB Model: 350C02 & 350B02 S/N S/N S/N Location Location S/N Location Location 11448 3 4 11443 11441 30712 8 5 31328 31329 31331 31351 6 9 11 31349 31330 10 31336 .12 31334 Aluminum LSC panel severance: ((Yes) / No ) 13 11439 Post-test visually inspected observations: Bolts & accelerometers did not loose torque. Data was obtained for all 13 accelerometers Test No.: 2 Date: 8/16/2012 Test Article Desc.: Aluminum Plate, 3'x6'x0.19" Test Article Configuration: Hanging Test Article Drawing #: 97M00201 Material: Aluminum 5052 S/N: Pathfinder Test Article Drawing #: 97M00202 Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00203\* Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00204\* Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00205 Shock Source LSC L/N: na. LSC Core Load: 22 <u>GR/FT</u> Explosive Material: <u>CH-6</u> Sheath: <u>Aluminum</u> Actual Length Used: <u>45</u>" Actual Length Used: \_ Accelerometer MFG: PCB Model: 350C02 & 350B02 Location S/N S/N S/N S/N Location Location Location 30712

11448 2 11441 11443 31328 31351 31329 3/33/ 6 31330 10 31334 11 31336 12 31349

Aluminum LSC panel severance: (Yesy No )

Post-test visually inspected observations: Bolts & accelerometers did not loose torque. Data was obtained for all 13 accelerometers.

Version:



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## Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

1.0

ET40/N	'ibration, Acoustics, and Shock T	eam	
Initial Tests for the Composite Materials	NESC-DEV-12-014	Revision:	
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### TEST DATA SHEET, cont.

Test No .:	3 Date: 9	/10/2012 Te	st Article D	esc.: Compos	ite Panel, 3'	x6'x0.2"	
Test Article	e Configurat	tion: Hang	ing				
Test Article	Drawing #	: 97M00201	MOD Mat	erial: IM7/R9	13 S/N: Pa	thfinder	
Test Article	Drawing #	: 97M00202	Material:	Aluminum S/	N: Pathfind	er	
Test Article	Drawing #	: 97M00203*	Material:	Aluminum S	N: Pathfinde	er	
Test Article	Drawing #	: 97M00204*	Material:	Aluminum S/	N: Pathfind	er	
Test Article	Drawing #	: 97M00205	Shock Sou	rce LSC	L/N: na		
LSC Core	e Load: 10 (	GR/FT Expl	osive Materi	al: RDX Sh	eath: Alumin	num	
Actual Le	ength Used:	48"			1946-1940 (1960) (1960) (1960) (1960)		
Accelerome	eter MFG: F	CB Model:	350C02				
Location	S/N	Location	S/N	Location	S/N	Location	S/N
1	31334	2	31340	3	31338	4	30712
5	31328	6	31333	7	40292	8	31351
9	31330	10	40295	11	31336	12	40274
Aluminum	LSC panel :	severance: (0	(es)/No)			13	11439
Post-test vi	sually inspe	cted observat	ions: Bolts	and accelero	moters did	not loose tor	w
Data was	obtained	for all 13 ac	celerometer	5.			

Note: \* Add "- MOD" to the Drawing # for the 95-tested configuration. fc. 2. 9/20/2012

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Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading				

# Tables

# Table 1 Equipment List

## **Data System Settings**

Table 2	Test T01 – Al. panel, 10	) gpf
Table 3	Test T02 - Al. panel, 22	2 gpf
Table 4	Test T03 – Al. panel, 10	) gpf



Equipment List NESC-DEV-12-014				
	9/10/	2012 Facto		
ΝΑΝΑΓ				
Data Acquisition	11EIVIS	JOI1200	7/26/2012	INFORMATION
Nicolet Channel 2	001-2	001-2	7/26/2013	A1
Nicolet Channel 3	001-2	001-2	7/26/2013	A1 A2
Nicolet Channel 4	001-3	001-3	7/26/2013	A2
Nicolet Channel F	001-4	001-4	7/26/2013	AS A4
Nicolet Channel 5	002-1	002-1	7/26/2013	A4
Nicolet Channel 6	002-2	002-2	7/26/2013	AS
Nicolet Channel 7	002-5	002-5	7/20/2013	A0
Nicolet Channel 8	002-4	002-4	7/26/2013	A7
Nicolet Channel 10	003-2	003-2	7/26/2013	A8
Nicolet Channel 11	003-3	003-3	7/26/2013	A9
Nicolet Channel 12	003-4	003-4	7/26/2013	A10
Nicolet Channel 13	004-1	004-1	//26/2013	A11
Nicolet Channel 14	004-2	004-2	//26/2013	A12
Nicolet Channel 15	004-3	004-3	7/26/2013	A13
Power Supply	M652262	AC47	1/11/2013	ch. 1-13
Torque Wrench	M659925	DHG92271	11/21/2012	55 & 28 ftlb.
Nicolet Analysis Software	TEAM256 V7.20	7.20	7/26/2012	Verification date
Shock Analysis Software	Shock Anal. Tool V1.2.5	1.2.5	5/21/2009	Verification date
System Analyzer	M624300	0793X3816	11/14/2012	
Electrostatic Locator	M624299	D13077	11/14/2012	
	Tests T01	and TO2		
NAME	NEMS	SERIAL NUMBER	CAL DUE DATE	INFORMATION
Accelerometer	M653302	11448	9/1/2012	A1
Accelerometer	M653298	11443	9/1/2012	A2
Accelerometer	M653296	11441	9/7/2012	A3
Accelerometer	M659353	30712	8/31/2012	A4
Accelerometer	M659525	31328	8/31/2012	A5
Accelerometer	M659526	31329	8/31/2012	A6
Accelerometer	M659528	31331	8/31/2012	A7
Accelerometer	M659547	31351	9/1/2012	A8
Accelerometer	M659527	31330	8/31/2012	A9
Accelerometer	M659531	31334	8/31/2012	A10
Accelerometer	M659533	31336	8/31/2012	A11
Accelerometer	M659545	31349	9/1/2012	A12
Accelerometer	M653294	11439	9/7/2012	A13
Torque Wrench	M659927	0709093897	11/21/2012	35 in-lb

### Table 1

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Composite Materials Subjected to Pyroshock Loading				

Test T03					
NAME	NEMS	SERIAL NUMBER	CAL DUE DATE	INFORMATION	
Accelerometer	M659531	31334	9/7/2013	A1	
Accelerometer	M659537	31340	9/7/2013	A2	
Accelerometer	M659535	31338	9/7/2013	A3	
Accelerometer	M659353	30712	9/7/2013	A4	
Accelerometer	M659525	31328	9/7/2013	A5	
Accelerometer	M659530	31333	9/6/2013	A6	
Accelerometer	M662961	40292	9/7/2013	A7	
Accelerometer	M659547	31351	9/6/2013	A8	
Accelerometer	M659527	31330	9/6/2013	A9	
Accelerometer	M662963	40295	9/7/2013	A10	
Accelerometer	M659533	31336	9/7/2013	A11	
Accelerometer	M662959	40274	9/7/2013	A12	
Accelerometer	M653294	11439	9/5/2013	A13	
Torque Wrench	M658783	2384	2/13/2013	35 in-lb	

Table 1 - cont.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: 1.0		
Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading					

#### TEAM256 SETTINGS

Time: 08:05:38 C:\TEAMPRO Storage Path: Filename: Data File Number: 001 Settings Path: C:\TEAM256 Settings File: NES01.SET D:\ATEST\NESC\_1\NEST01\RAWDAT~1 Export Path: Export Format: FAMOS Average Blocks: No Between Cursors: No BE1 Frequency A : 1.0000 MHz(Internal) 48000 Samples (48.00 ms) 1000576 Samples (1.001 s) Pre Trigger : Segment A : Number of Blocks : Digital Event Channels : 0 Analog Channels : Nr. Name Min 1 XXX\_1 -55.56 2 NES\_2 -64.81 Max Units 55.56 kg's pk 64.81 kg's pk 64.81 kg's pk Coup. Amp. Filter Trigger GND 33.00 k Off + + DC DC DC DC DC Basic 33.00 k 3 NES\_3 -64.81 + 33.00 k Basic 64.05 kg's p. 56.60 kg's pk 56.07 kg's pk -54.05 -56.60 -56.07 33.00 k 33.00 k 33.00 k 45 NES\_4 Basic NES\_5 NES\_6 NES\_7 + Basic 6 Basic DC DC GND -58.25 58.25 kg's pk 33.00 k Basic 55.56 kg's pk 55.56 kg's pk 56.07 kg's pk 54.05 kg's pk 8 -55.56 -55.56 NES\_8 4 33.00 k Off XXX\_9 -55.56 NES\_10 -56.07 NES\_11 -54.05 9 33.00 k OFF + DC DC 10 33.00 k Off 11 33.00 k Off 57.69 kg's pk 55.56 kg's pk 55.56 kg's pk 55.56 kg's pk 53.57 kg's pk 12 NES\_12 -57.69 DC DC DC DC 33.00 k Off NES\_13 -55.56 33.00 k 33.00 k 13 Off NES\_13 -55.56 NES\_14 -55.56 NES\_15 -53.57 ROC\_16 -55.56 ROC\_17 -55.56 Off 14 33.00 k Off 15 DC DC DC DC 16 55.56 kg's pk + 33.00 k Off 17 55.56 kg's pk + 33.00 k Off ROC\_18 -55.56 ROC\_19 -55.56 ROC\_20 -55.56 55.56 kg's pk 55.56 kg's pk 55.56 kg's pk 18 + 33.00 k 33.00 k Off 19 Off + DC 33.00 k 20 Off 20 ROC\_20 -55.56 55.56 kg's pk DC Engineering Units Scaling XXX\_1 0 + 9.2593 k \* Voltage (g's pk) NES\_2 0 + 9.2593 k \* Voltage (g's pk) NES\_3 0 + 9.2593 k \* Voltage (g's pk) NES\_4 0 + 9.0090 k \* Voltage (g's pk) NES\_5 0 + 9.4340 k \* Voltage (g's pk) NES\_6 0 + 9.3458 k \* Voltage (g's pk) NES\_7 0 + 9.7087 k \* Voltage (g's pk) NES\_8 0 + 9.2593 k \* Voltage (g's pk) VYY 0 0 + 9.2593 k \* Voltage (g's pk) 0 + 9.2593 k \* Voltage (g's pk) 0 + 9.3458 k \* Voltage (g's pk) XXX\_9 NES\_10 0 + 9.0090 k \* Voltage (g's pk) 0 + 9.6154 k \* Voltage (g's pk) 0 + 9.2593 k \* Voltage (g's pk) NES\_11 NES 12 NES\_13 0 + 9.2593 k \* Voltage (g's pk) NES\_14 0 + 0 + 8.9286 k \* Voltage (g's pk) NES\_15 0 + 9.2593 k \* Voltage (g's pk) 0 + 9.2593 k \* Voltage (g's pk) 0 + 9.2593 k \* Voltage (g's pk) ROC\_16 ROC\_17 ROC\_18 0 + 9.2593 k \* Voltage ROC\_19 (g's pk) 0 + 9.2593 k \* Voltage (g's pk) ROC\_20 Trigger Settings : Auto Trigger: Off Table 2 - Test T01

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Date: 08-10-2012



EFRING & Say	NASA Engineering and Safety Center	Document #:	Version:
A REAL PROPERTY OF	<b>Technical Assessment Report</b>	NESC-RP- 12-00783	1.0
Title: Empir	ical Model Development for Predicting Shock Ro Composite Materials Subjected to Pyroshock Loa	esponse on ding	Page #: 314 of 793
Date: Time:	TEAM256 SETTINGS 09:18:58		
***** File Setti Setti Expor Expor Avera Betwe	<pre>v************************************</pre>	2	
* * * * *	**************************************		
BE1 Freq Pre Segm Numk Digi Anal	nuency A : 1.0000 MHz(Internal)   Trigger : 48000 Samples (48.00 ms)   nent A : 1000576 Samples (1.001 s)   per of Blocks : 1   tal Event Channels : 0   og Channels : 1		
Nr 1 2 3 3 4 4 5 6 7 7 7 8 9 9 10 11 12 13 13 14 15 16 17 18 19 9 9 9 9 9 9 9 9 10 11 12 12 13 14 14 14 12 13 14 14 14 14 14 14 14 14 14 14 14 14 14	Name   Min   Max   Units   Coup. Amp.   Filter   Trigger     XXX_1   -55.56   55.56   kg's pk   GND   +   33.00 k   Off     NES_2   -28.85   28.85 kg's pk   DC   +   33.00 k   Basic     NES_3   -31.58   31.58 kg's pk   DC   +   33.00 k   Basic     NES_4   -30.00   30.00 kg's pk   DC   +   33.00 k   Basic     NES_5   -28.30   28.30 kg's pk   DC   +   33.00 k   Basic     NES_6   -28.04   28.04 kg's pk   DC   +   33.00 k   Basic     NES_8   -28.30   28.30 kg's pk   DC   +   33.00 k   Off     XX_9   -55.56   55.56 kg's pk   DC   +   33.00 k   Off     NES_11   -27.03   27.03 kg's pk   DC   +   33.00 k   Off     NES_11   -27.78   27.78 kg's pk   DC   +   33.00 k   Off		×
Engi Engi XX NE NE NE NE XX NE NE NE NE NE NE NE NE NE NE NE NE NE	<pre>neering Units Scaling XL1 0 + 9.2593 k * Voltage (g's pk) SS_2 0 + 9.6154 k * Voltage (g's pk) SS_3 0 + 10.526 k * Voltage (g's pk) SS_4 0 + 10.000 k * Voltage (g's pk) SS_5 0 + 9.4340 k * Voltage (g's pk) SS_6 0 + 9.3458 k * Voltage (g's pk) SS_7 0 + 9.5238 k * Voltage (g's pk) SS_8 0 + 9.4340 k * Voltage (g's pk) SS_10 0 + 9.3458 k * Voltage (g's pk) SS_11 0 + 9.0090 k * Voltage (g's pk) SS_12 0 + 9.4340 k * Voltage (g's pk) SS_13 0 + 9.2593 k * Voltage (g's pk) SS_14 0 + 9.2593 k * Voltage (g's pk) SS_15 0 + 8.9286 k * Voltage (g's pk) SS_15 0 + 8.9286 k * Voltage (g's pk) SC_16 0 + 9.2593 k * Voltage (g's pk) SC_17 0 + 9.2593 k * Voltage (g's pk) SC_16 0 + 9.2593 k * Voltage (g's pk) CC_17 0 + 9.2593 k * Voltage (g's pk) CC_18 0 + 9.2593 k * Voltage (g's pk) CC_19 0 + 9.2593 k * Voltage (g's pk) CC_20 0 + 9.25</pre>		
	Table 4 - Test T03		
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## **B2.** Group I (Monolithic Panel Tests)

The test report documenting pathfinder group tests 4, 5, and the task assessment baseline Group I tests numbers 1 through 10 are documented in the attachments below.



## NASA Engineering and Safety Center Technical Assessment Report

Version:

1.0

### Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812



Reply to Allm of: ET40-15-006

- TO: EV32/David O. Ordway
- FROM: ET40/Timothy C. Driskill
- SUBJECT: Additional Initial Tests and Start of the Composite Materials Pyroshock Development Test, NESC-DEV-12-028

January 20, 2015

REF: ED73.1

The solid composite pathfinder panel and solid composite panel test articles were tested in the ET40 Pyrotechnic Shock Facility, building 4619, room 170. Testing was completed on February 22, 2013. The test was run in accordance with Test and Checkout Procedure, (TCP) NESC-DEV-12-028. Two tests were run using composite pathfinder panels and five tests were run on the solid composite panels for Group I – Tests 01 to 05. The accelerometer test setup is shown in the photographs section of this report. Accelerometer location A4 was not used in Pathfinder test no. 4 due to an improperly threaded insert installed at that location. No post-test observations were noted.

Please direct any questions or comments regarding this test to Mr. Craig Garrison at (256) 544-7197 or craig.garrison@nasa.gov.

Timothy C. Driskill Branch Chief Structural Dynamics Test Branch

Enclosure cc:

ET01/File (w/o enclosure) ET40/File C105/Steven J. Gentz ES22/David S. Parsons

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Test Matrix As Run				
Test	Date	Panel ID	Test ID	
1	11-30-12	Composite Pathfinder #4	Initial Test #4	
2	12-5-12	Composite Pathfinder #5	Initial Test #5	
3	1-23-13	0320A001	Group 1 Test 1	
4	1-29-13	0320A002	Group 1 Test 2	
5	2-5-13	0320A004	Group 1 Test 4	
6	2-8-13	0320A003	Group 1 Test 3	
7	2-22-13	0320A005	Group 1 Test 5	

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## NESC-DEV-12-028 Composite Materials Shock Test

## Test #1 Accelerometer Data Composite Pathfinder Panel 4

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## NESC-DEV-12-028 Composite Materials Shock Test

## Test #2 Accelerometer Data Composite Pathfinder Panel 5
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## NESC-DEV-12-028 Composite Materials Shock Test

## Test #3 Accelerometer Data Panel 0320A001

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## NESC-DEV-12-028 Composite Materials Shock Test

## Test #4 Accelerometer Data Panel 0320A002

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## NESC-DEV-12-028 Composite Materials Shock Test

## Test #5 Accelerometer Data Panel 0320A004

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## NESC-DEV-12-028 Composite Materials Shock Test

## Test #6 Accelerometer Data Panel 0320A003

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## NESC-DEV-12-028 Composite Materials Shock Test

## Test #7 Accelerometer Data Panel 0320A005

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Composite Materials Subjected to Pyroshock Loading				

George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812 NESC-DEV-12-028 11/15/2012

## TEST AND CHECK-OUT PROCEDURE

ET40 / VIBRATION, ACOUSTICS, AND SHOCK TEAM

## ADDITIONAL INITIAL TESTS AND START OF THE COMPOSITE MATERIALS PYROSHOCK DEVELOPMENT TEST

## This Procedure Describes Safety Critical Operations

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ET40 / Vibration, Acoustics, and Shock Team			am
Additional Initial Test Materials Pyroshock	s and Start of the Composite	NESC-DEV-12-028	Revision:
PREPARED BY:	John Ciag Danie	~	11/16/2012
	John Craig Garrison / E Test Engineer	ET40	Date
APPROVED BY:	Kathof One	n	11/16/12
	Kathy L. Owen / ET40 Deputy Branch Chief	1 Decel	Date
APPROVED BY:	David Ordway / EV32 Aerospace Engineer, P Structural & Mechanica Test Requester	duray grotechnics al Design Branch	<u>11/16/201</u> . Date
APPROVED BY:	David Barsons		11/16/2012
	David Parsons / ES22 Structural Dynamics Mechanical, Thermal a	nd Life Support Brancl	Date



Version:

1.0

# Title:Page #:Empirical Model Development for Predicting Shock Response on<br/>Composite Materials Subjected to Pyroshock LoadingPage #:563 of 793

#### 1.0 <u>INTRODUCTION</u>

1.1 PURPOSE

The purpose of this procedure is to define the steps necessary to perform a pyrotechnic shock test in the Pyrotechnic Shock Facility in Building 4619 using pyrotechnic devices.

Initial Test Articles: <u>3'x6'x0.2" solid composite pathfinder panel with LSC plate and LSC backing plate</u>. One panel with all ply orientations at 0 degrees, and one panel with all ply orientations at 90 degrees, as specified in table II test 4 & 5 of the applicable test plan.

Test Matrix Test Articles: <u>3'x6' solid composite panel with LSC plate and LSC backing plate.</u> The first 5 test articles of the test matrix are described in Table III, Group I, tests <u>1 to 5.</u>

Program: <u>NESC</u> Type of Test: <u>Pvrotechnic Shock Development Test</u> Test Purpose: <u>To capture the acceleration time history of initial test setup and</u> <u>instrumentation checkout panels</u>.

The Pyrotechnic Shock Facility is located in Rooms 170, 170A and 170B of Building 4619. Room 170A is designated as the Control Room. The area between Room 169 and 170 is used for storage of secondary pyrotechnic devices. Room 170B is used for storage of initiators. All detonation of pyrotechnic devices will be in Room 170.

1.2 SCOPE

This document contains the steps and/or references the procedure to conduct the test.

2.0 <u>SAFETY</u>

Follow all emergency and safety requirements specified in ET01-DYN-SHK-FOP-001.

2.1 <u>Responsibilities</u>

The Test Engineer will be responsible for all activities occurring in the hazardous test area and for the safety of personnel involved in the test activities. It is the responsibility of each individual in a test program to fully comply with the requirements of this document and to report any individual not complying. Failure to do so could lead to serious personnel injuries or death.

- 3.0 TEST REQUIREMENTS AND INFORMATION
- 3.1 DOCUMENTS
- 3.1.1 APPLICABLE DOCUMENTS



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#### Title: **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

Test Requirements: Pyroshock Response Characterization of Composite Materials Test Plan Revision A, NESC Task # TI-12-0783 (SLS ADO-21), 11/8/2012

Test Procedure: ET01-DYN-SHK-FOP-001 Pyrotechnic Shock Tests

PANEL #4 - #5 COMPOSITE PATHFINDER PANEL 97M00200-GRP I-TEST 1-5 COMPOSITE TEST PANEL, GROUP I, TEST #1-#5 97M00202 LSC BACKING PLATE, COMPOSITE TEST PANEL PATHFINDER 97M00203-MOD LSC PLATE, COMPOSITE TEST PANEL PATHFINDER 97M00204-MOD-2-10 LSC SHIM, COMPOSITE TEST PANEL 10 GPF LSC 97M00204-MOD-2-22 LSC SHIM, COMPOSITE TEST PANEL 22 GPF LSC 97M00205 10 GR/FT LSC, COMPOSITE TEST PANEL PATHFINDER

3.1.2 REFERENCED DOCUMENTS

ET01-DYN-OWI-001 Documentation Control

ET01-DYN-OWI-002 Test Operation Procedure Preparation and Change Control

- 3.2 TEST INFORMATION
- 3.2.1 The instrumentation locations are given in the drawings listed in the applicable documents and appendix A for the test.
- 3.2.2 Pyrotechnic shock tests may be performed on the test article in the order and configuration directed by the test requester.
- 3.2.3 The shock test will be performed on a room temperature test article.
- 3.3 TEST REQUIREMENTS
- 3.3.1 The Test Engineer will be in charge of all test preparations and activities.
- 3.3.2 All activities will be coordinated with the Test Engineer.
- 3.3.3 All changes to the procedure will be coordinated with the Test Engineer.
- **3.3.4** The development test articles will be tested with pyrotechnic shock test runs as directed by the test requester. The test article information will be recorded in this TCP.
- 4.0 <u>TEST DATA</u>
  - a. The test data includes a time history of the real time shock recorded over a 20 millisecond or longer interval and the units are g's peak versus time.
  - b. The second plot is a Shock Response Spectrum (SRS) using 5% damping and a 1/6 octave shock spectrum analyzer. The SRS is computed over the frequency



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	Additions	I Initial Tests and Start of	the Composite   NESC-DEV-12.	028	Revision:	
	Materials	Pyroshock Development T	est Date: 11/15/20	012	Page 4 of 15	
		0				
		band from 5	0 to 10,000 Hertz. The SRS	units are g's	versus frequency.	
		c. The data wil	I be acquired on a Nicolet E	E256LE data	a acquisition system and the	
		SRS analysis	s will be performed using a	personal com	puter and the Shock	
		Analysis Too	ol Analysis Software.		8 670	
		d. Sample rate	of 1 million samples per sec	cond will be u	used for response from the	
20		acceleromete	ers.			
		• • • • • • • • • • • • • • • •	XX M/24617 6	ToTachE #	M659924 Govel-Tes	+1
	5.0	TEST SETUP	Call gladana Anel 3	1-1013 h	CH: 8/28/17 Dun: 2/28/13	-
	0.0	1001 00101	Lat the sole of s	1012.5	and Group 1 - Test 2	
<b>N</b> S	5.1	TEST ARTICLE A	ND SHOCK PLATE SET	1P	and Group 1 - Test 4	
	5.1	TEST ARTICLE /	IND SHOCK I EATE SET	01	and Group I - Test 3	
		a The test set	un is shown in Annandiy A		- Group 1 - Test 5	
		a. The test sett	ip is shown in Appendix A.	in a staann an	applace and shealdas	
6.00	40 ×	b. Suspend the	shock plate from certing us	comparent to	Late must for second in (AI)	)
		c. Suspend I a	ccelerometer near the plate.	Connect to	the system for recording.	
	10	d. Instrument s	shock plate. Each acceleror	neter's torque	Will be to 30±5 in10.	: 8/13/12
		I orque wrei	nch: 11658785 1	orque value:	33 in-16. "Dye. anonis	
		e. LSC plate a	nd LSC backer plate to lest	Panel. Each	<sup>1</sup> / <sub>2</sub> - <u>1</u> ) bolt's torque will be	
		to 55 7- 5 1	Torque wrench: 1/69.	5410	Forque value: <u>35 ft-1b</u>	
		Barght Barris a	Une: d	24(13	* 28+++-16	
	6.0	TEST OPERATIO	N Cal; 8/	241192	4 corner hole	s Dim
					m/uuan 3	(4
	6.1	ADDITIONAL IN	ITIAL TESTS OF THE CO	MPOSITE M	ATERIALS Duni 2 /28/23	
		PYROSHOCK DE	V TEST		Cd: 8/28/13	
		Shock Source I Actual Length U Measure the over	LSC Core Load: <u>10 GR/FT</u> Jsed: <u><b>48.5</b>"</u> erall width of the FLSC: (	Explosive N	aterial: <u>RDX</u> Sheath: <u>Al</u> has	wrong three used.
199 A. (*)	e manife the	Measure the wie	dth of the FLSC inside the a	pex (inverted	chevron): 0.094"	
				1		
		b. Verify that the	shock plate is ready for test	ing per sectio	on 5.1.	
		<ol> <li>At the start of e</li> </ol>	each test day, complete ET0	1-DYN-SHK	-FOP-001, section 6.	
		d. Photograph the	locations and orientations of	of all accelero	ometers.	
		e. Perform the tes	t per sections 7, 8, and 9 of	ET01-DYN-	SHK-FOP-001.	
		f. Photograph the	test setup after the test. Ph	otograph and	document any post-test	
		visually inspect	ted observations under this	test number in	n appendix B.	
		g. Verify that the	test run has been completed	l.	VICA II-	30-2012
			ates			
	6.2	ADDITIONAL IN	ITIAL TESTS OF THE CO	MPOSITE N	IATERIALS	
		PYROSHOCK DE	V. TEST	- 14		
			5 · ·			
		a. Record and ve	rify the test information bel	ow and in an	pendix B.	
		a. Itecold and ve	ing are use information ber	on and in app		
					02	
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#### **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

17 <u>76</u>	ET40 / Vibratia	n. Acquistics, and Shock Tea	im j
Additional	Initial Tests and Start of the Composite	NESC-DEV-12-028	Revision:
Materials	yroshoek Development Test	Date: 11/15/2012	Page 5 of 15
	Pathfinder Test No.: <u>5</u> Da <u>Composite Pathfinder Panel</u> ,	tte: <u>12-5-2012</u> Test A all plies are <b>D</b> + deg	rticle Desc.: <u>1M7/R913 Solid</u> Res. 3'x6'x0.2"
	Shock Source LSC Core Loa Actual Length Used:48.5	d: <u>10 GR/FT</u> Explosi	ive Material: <u>RDX</u> Sheath: <u>Al</u>
	Measure the overall width of Measure the width of the FLS	the FLSC: 0.131"	erted chevron): o and
the states		e inside the uper (int	
an 1977 a San Bang San Bang San Bang San Bang	<ul> <li>b. Verify that the shock plate is</li> <li>c. At the start of each test day,</li> <li>d. Photograph the locations and</li> </ul>	complete ET01-DYN- orientations of all acc	SHK-FOP-001, section 6. elerometers.
	f. Photograph the test setup aft	er the test. Photograph	and document any post-test
	visually inspected observatio	ons under this test num	ber in appendix B.
\$	g. Verify that the test run has be	een completed.	VICE 12-5-2012
6.3	START OF THE COMPOSITE	MATERIALS PYROS	SHOCK DEV. TEST
	a. Record and verify the test in	formation below and in	appendix B.
andra Antonio di se	Group I Test No.: 1 Date	: 1-23-2013 Test Arti	icle Desc.: IM7/TC350 Solid
te de s	Composite Panel, 3'x6' Thie	ckness: 0.200" Ply: Fe	bric Orientation: 0-Deg., 18 ply
ali e Na	Shock Source LSC Core Loa	id: <u>10 GR/FT</u> Explosi "	ve Material: <u>RDX</u> Sheath: <u>Al</u>
	Measure the overall width of	the FLSC: DISI"	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1
	Measure the width of the FLS	C inside the apex (inv	erted chevron): <b>0.094"</b>
8	b. Verify that the shock plate is	ready for testing per s	ection 5.1.
874.	c. At the start of each test day,	complete ET01-DYN-	SHK-FOP-001, section 6.
	<ul> <li>c. Photograph the locations and e. Perform the test per sections.</li> </ul>	7 8 and 9 of FT01-D	VNLSHK_EOP.001
10.20	f. Photograph the test setun after	er the test. Photograph	and document any post-test
8. 19.	visually inspected observatio	ns under this test num	ber in appendix B.
1	g. Verify that the test run has be	een completed.	VQCA 1-23-201
6.4	START OF THE COMPOSITE	MATERIALS PYROS	SHOCK DEV. TEST
	a. Record and verify the test inf	formation below and in	appendix B. $a = a = a = a = a = a = a = a = a = a $
	Group I Test No.: 2 Date:	1-29-2013 Test Artic	cle Desc.: IM7/TC350 Solid
	Composite Panel, 3'x6' Thic	kness: 0.200" Ply: F	abric
10 - 40 54	Orientation: $\pm 45^{\circ}/-45^{\circ}$ , $0^{\circ}$ (2)	(), $+45^{\circ}/-45^{\circ}$ , $90^{\circ}$ (2x).	. 18 ply
	Shock Source LSC Core Loa	a: <u>10 GR/FT</u> Explosi	ve Material: <u>RDX</u> Sheath: <u>Al</u>
	Measure the overall width of	the FLSC: 0 131 *	10 34
	Measure the width of the FLS	C inside the apex (inv	erted chevron): 0.094"
	b. Verify that the shock plate is	ready for testing per s	ection 5.1.
	2 M		
	S	251 of 268	

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Additional	Initial Tests and Start of the Composite N	ESC-DEV-12-028	Revision:	
Materials P	yroshock Development Test	ate: 11/15/2012	Page 6 of 15	
	c. At the start of each test day, co	mplete ET01-DYN	-SHK-FOP-001, section	6.
3-3	d. Photograph the locations and o	rientations of all ac	celerometers.	
	e. Perform the test per sections 7,	8, and 9 of ET01-I	DYN-SHK-FOP-001.	
	f. Photograph the test setup after	the test. Photogram	h and document any post	-test
	visually inspected observations	under this test nur	ober in appendix B.	
	g Verify that the test run has been	n completed.	iter in appendit bi	Voca 1-29-201
	g. verify that the test run has been	i completed.		0.00
	a the second		-	
65	START OF THE COMPOSITE M	ATERIALS PVRC	SHOCK DEV TEST	
0.5	START OF THE COMPOSITE M	ATEMALSTIK	SHOCK DEV. TEST	
	Devel 1 - Code to the			
	a. Record and verify the test infor	mation below and	in appendix B.	
		Tanel	0 # 0320A003	
	Group I Test No.: $\underline{J}$ Date: $\underline{A}$	-8-20/3 Test Art	icle Desc.: <u>IM7/1C350 S</u>	olid
*	Composite Panel, 3'x6' Thickr	less: <u>0.300"</u> Ply:	Tape	
	Orientation: <u>+45°/-45°</u> , 0° (2x).	+45°/-45°, 90° (2x	<u>), 54 ply</u>	
	Shock Source LSC Core Load:	10 GR/FT Explos	sive Material: RDX Sher	ath: <u>Al</u>
	Actual Length Used: _ 48.5"			40
	Measure the overall width of the	e FLSC: 0.131"		
	Measure the width of the FLSC	inside the apex (in	verted chevron): 0.09"	1.
		1 ,		
	b. Verify that the shock plate is re	ady for testing per	section 5.1.	
	c. At the start of each test day, co	mplete ET01-DYN	-SHK-FOP-001, section (	6.
1	d. Photograph the locations and o	rientations of all ac	celerometers.	
S. Sec.	e. Perform the test per sections 7.	8, and 9 of ET01-I	OYN-SHK-FOP-001.	
	f. Photograph the test setup after	the test. Photogram	h and document any post	-test
	visually inspected observations	under this test nur	aber in appendix B.	
	g. Verify that the test run has been	n completed		VRCA 2-8-20
	5. Corry dia die cost fait has been	. compresed		
6.6	START OF THE COMPOSITE M	ATERIALS DVDC	SHOCK DEV TEST	
0.0	START OF THE COMPOSITE M	ATERIALS FIRU	SHOCK DEV. IESI	
	Depend and south the test luft	motion below and	in annandiy D	
	a. Record and verify the test infol		17 # 03104004	
	C. IT.IV. U.S. 1	Tanes	ista Deces Digitar Corole	
	Group I Test No.: 4 Date:	Test Art	Icie Desc.: <u>IM7/1C350 S</u>	ond
	Composite Panel, 3'x6' Thickr	less: <u>0.300</u> " Ply:	Fabric	
	Orientation: $\pm 45^{\circ}/-45^{\circ}$ , $0^{\circ}$ (2x),	+45°/-45°, 90° (2x	<u>), 27 ply</u>	
	Shock Source LSC Core Load:	22 GR/FT Explos	sive Material: CH-6 She	eath: <u>Al</u>
	Actual Length Used: 4'			i
	Measure the overall width of th	e FLSC: 0.178'		10
54	Measure the width of the FLSC	inside the apex (in	verted chevron): () 120"	
		(a)	0.100	2
	b. Verify that the shock plate is re	ady for testing per	section 5.1.	
	c. At the start of each test day, co	mplete ET01-DYN	-SHK-FOP-001, section	6.
	d. Photograph the locations and o	rientations of all ac	celerometers.	
	e Perform the test per sections 7	8 and 9 of FT01-I	DYN-SHK-FOP-001	
	f Photograph the test seture after	the test Photogram	h and document any nost	-test
	1. Thorograph the test setup after	the test. Photograp	and document any post	tost



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#### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

	Additional	E 140 / Vibrati Initial Tests and Start of the Composite	NESC-DEV-12-028	am Revision:
ж. Н	Materials P	yroshock Development Test	Date: 11/15/2012	Page 7 of 15
		the last state have all		has been and by D
		Visually inspected observation	ons under this test num	iber in appendix B.
		g. Verify that the test run has t	been completed.	V JCH 2
	< <b>7</b>	START OF THE COMPOSITE	MATERIALORYDO	SUCCE DEN TEST
	6.7	START OF THE COMPOSITE	MATERIALS PYRO	SHOCK DEV. TEST
1.5	3	a. Record and verify the test in	formation below and i	n appendix B.
			fanel	ID: Ø320 AØ0 5
		Group I Test No.: <b>b</b> Date	: 2-22-2013 Test Arti	cle Desc.: IM7/TC350 Solid
		Composite Panel, 3'x6' Thi	ckness: <u>0.200"</u> Ply: <u>'</u>	Таре
		Orientation: <u>+45°/-45°, 0° (2</u>	x), $+45^{\circ}/-45^{\circ}$ , $90^{\circ}$ (2x)	) <u>, 38 ply</u>
		Shock Source LSC Core Lo	ad: 22 GR/FT Explos	ive Material: CH-6 Sheath: Al
		Actual Length Used:	' <b>4'</b>	
		Measure the overall width of	"the FLSC: 0.178"	
		Measure the width of the FL	SC inside the apex (inv	verted chevron): 0.120"
		b. Verify that the shock plate is	s ready for testing per s	section 5.1.
		c. At the start of each test day,	complete ET01-DYN-	SHK-FOP-001, section 6.
		d. Photograph the locations an	d orientations of all acc	celerometers.
	14. 16.	e. Perform the test per sections	7, 8, and 9 of ET01-D	YN-SHK-FOP-001.
		f. Photograph the test setup aff	er the test. Photograph	h and document any post-test
		visually inspected observation	ons under this test num	ber in appendix B.
		g. Verify that the test run has b	een completed.	VACD
				2-22-201
				7-7
	7.0	RECORDS		
	7.0	<u>RECORDS</u>		
See.	S. 2010	The test report for this test will	control and include the	following records:
		a This "AS PUN" TCP	control and monute the	tonowing records.
		a. This AS KON TCF.	out list	
		b. The test data and the equipm	ent list.	
		The test second is second all of her I	TOL DVNLOWLOOT	Decementarian Control
		The test report is controlled by	5101-DYN-OWI-001,	Documentation Control.
		However, due to the ITAR desig	gnation for the test resu	ilts, the test report and data will
		be securely controlled. The test	report will be availabl	e no later than 30 days after test
		completion. The Test Requirem	ients will not be includ	ed in this TCP or in the report,
		but a copy may be filed with the	report for future refer	ence.
	10.0 9210.09			
	8.0	TOOLS, EQUIPMENT, AND N	ATERIALS	
		The equipment used during this	test will be listed in a t	table as part of the test report.
		The list will include test equipm	ent calibration due dat	es.
		2		
	9.0	PERSONNEL TRAINING ANI	<b>CERTIFICATION</b>	
		Personnel certified as Propellant	and Explosive Handle	er are required to conduct this
		test		e te se energia de la contra de l
16 - 13				
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		25	252 -4 200	

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ET40 / Vibrati	on, Acoustics, and Shock Te	am	
Additional Initial Tests and Start of the Composite	NESC-DEV-12-028	Revision:	
Materials Pyroshock Development Test	Date: 11/15/2012	Page 8 of 15	

#### POST-TEST VERIFICATION

The Test and Check-out Procedure NESC-DEV-12-028 has been satisfactorily completed and documented.

2/22/2013 Date Test Engineer / ET40

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: 1.0	
Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading				

## APPENDIX A

TEST SETUP



	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: 1.0	
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## APPENDIX B

TEST DATA SHEET


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Title:

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		ET407	Vibration, A	coustics, and Shoo	k Team	-1	
Additional In	itial Tests and S	itart of the Comp	osite NE	SC-DEV-12-028	Re	vision:	
Materials Pyr	roshock Develop	ment Test	Da	te: 11/15/2012	Pa	ge 12 of 15	
Pathfinder	Test No · 4	T	EST DA	ATA SHEE	Г с : IM7/R9	13 Solid Com	inosite
Pathfinder Test Articl	Panel, all 38 e Configurat	tape plies are	90 H deur	568, 3'x6'x0.2		is sond com	posite
Test Articl	e Drawing #	: Panel #4-#5	Materia	I: IM7/R913 S	olid Compo	site S/N: Pat	hfinder
Test Articl	e Drawing #	: 97M00202	Material:	Aluminum S	/N: Pathfin	der	
Test Articl	e Drawing #	: 97M00203-N	MOD M	aterial: Alumin	num S/N: H	athfinder	
Test Articl	e Drawing #	97M00204-N	MOD-2-10	0 Material: A	luminum S	S/N: Pathfinde	er
Test Articl	e Drawing #	: <u>97M00205</u>	Shock So	urce LSC I	N: none		
LSC Cor	e Load: 10 C	GR/FT Explo	sive Mate	erial: RDX Sh	neath: Alum	inum	
Actual L	ength Used:	48.5"			1		
Accelerom	eter MFG: P	CB Model: 3	<u>50C02</u> &	350 802		1	
Location	S/N	Location	S/N	Location	S/N	Location	S/N
	31334	2	31340	3	31338	4	3071
5	31328	6	3 333		40292	8	31351
9	31330	10	40295	i i kl	31336	12	40274
Aluminum	LSC panel s	everance: (Y	esy No)			L_13_	1 1145
Post-test v	isually inspec	cted observati	ons. Ace	elementers a			
its to gen 13 accele	el, left side All other meters.	No test art	slightly ticle anon	d II held their below their to nalies.	с · IM7/R9	to rave . tr he bottom rigita ta was obtain	n the t
vf the pan its to good 13 accele	el, left side All other remeters. Test No.: <u>5</u> Panel, all 38	bolts were. No test and Date: 12-5	2012 Te	d !! held their beliw their to naliss. est Article Des tes, 3'x6'x0.2'	c.: <u>IM7/R9</u>	to rave . Fr he bottom rigt ta was of the 13 Solid Com	en the to ht bithe had for a posite
Pathfinder Pathfinder Test Articl	el, left side All other meters. Test No.: <u>5</u> Panel, all 38 e Configurat	Date: 12-5 Date: 12-5 Date: 12-5	-2012 Te	d II held their belie their to naliss. est Article Des est 3'x6'x0.2'	c.: <u>IM7/R9</u>	to rave . Fr he bottom rigt ta was of the 13 Solid Com	en the the het bit he ned for a posite
Pathfinder Pathfinder Pathfinder Test Articl Test Articl	el, left side All other om et vs. Test No.: <u>5</u> Panel, all 38 e Configurat e Drawing #	Date: 12-5 tape plies are ion: Hangin Partel #4-#5	-2012 -2012 Guideger Material	d II held their belie their to naliss. Starticle Des Starticle Des	<u>. 4 пр / са</u> + с.: <u>IM7/R9</u> - - - -	to rave . Fr he bottom rigt ta was of the 13 Solid Com	n the the ht bit he nod for a posite hfinder
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	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: <b>1.0</b>			
Title: Empirical Model Development for Predicting Shock Response on						

ET40 / Vibration, Acoustics, and Shock Team					
Additional Initial Tests and Start of the Composite	NESC-DEV-12-028	Revision:			
Materials Pyroshock Development Test	Date: 11/15/2012	Page 14 of 15			

### TEST DATA SHEET, cont.

Fest Article	e Configurat	ion: Hang	ing	in the second second			
Test Article	Drawing #	: 97M00200-	GRP I-TES	T1-5 Mater	ial: IM7/TC	350 S/N: 0	3204003
Fest Article	Drawing #	: 97M00202	Material: A	Aluminum S.	N: Pathfind	er	
<b>Fest</b> Article	Drawing #	: 97M00203-	MOD Mat	erial: <u>Alumir</u>	um S/N: Pa	thfinder	
Test Article	Drawing #	: 97M00204-	MOD-2-10	Material: A	luminum S/	N: Pathfinde	er
LSC Core	Drawing #	: <u>97M00205</u> <u>iR/FT</u> Explo	Shock Sou osive Materi	rce LSC ial: <u>RDX</u> Sh	L/N: <u>ne</u>	num	
Accelerom	eter MFG. P	CB Model	350C02				
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a	21220	Ģ.	51535		70292	12	3/39/
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Aluminum	LSC panel s	everance:	( INO )			13	1421
Group: <u>I</u> T Panel: 27 fa	est No.: <u>04</u> abric plies w	Date: <u>2-9</u> ith +45°/-45°	<b>-20/3</b> Test °, 0° (2x), +4	Article Desc. 45°/-45°, 90°	: <u>IM7/TC35</u> (2x); 3'x6'x	0 Solid Com (0.3"	posite
Group: 1 T Panel: 27 fr Fest Article Fest Article Fest Article Fest Article Fest Article Fest Article LSC Core	est No.: <u>04</u> abric plies w configurat Drawing # Drawing # Drawing # Drawing # Drawing # Load: 22 C	Date: <b>2-5</b> ith +45°/-45° ion: <u>Haag</u> 97M00200- 97M00203- 97M00203- 97M00204- 97M00205 R/FT Explo	<b>5-2013</b> Test <b>c</b> , 0° (2x), +4 <b>GRP I-TES</b> Material: <u>/</u> <u>MOD</u> Mat <u>MOD Pat</u> Shock Sou osive Materi	Article Desc. 45°/-45°, 90° <u>T 1-5</u> Mater Aluminum S/ erial: <u>Alumir</u> Material: <u>A</u> rce LSC ial: CH-6 Sh	: IM7/TC35 (2x); 3'x6'x ial: IM7/TC ial: IM7/TC N: Pathfind um S/N: Pa luminum S/ L/N: eath: Alumi	0 Solid Com 0.3" 350 S/N: <u>1</u> sthfinder N: Pathfinder (e_num	p <u>osite</u> 032 <i>0A 00</i> 4
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Group: 1 T Panel: 27 fa Fest Article Fest Article Fest Article Fest Article Fest Article Fest Article LSC Core Actual Le Accelerome Location	est No.: <u>04</u> abric plies w e Configurat b Drawing # b Drawing # b Drawing # b Drawing # c Drawing # b Drawing # c Drawing # b Drawing #	Date: 2-9 ith +45°/-45' 97M002002 97M00202 97M00203- 97M00204- 97M00204- 97M00205 07/M	GRP 1-TES Material: <u>4</u> MOD Mat MOD-2-10 Shock Sou osive Materia 350C02 S/N	Article Desc. 45°/-45°, 90° <u>T 1-5</u> Mater <u>Aluminum</u> S erial: <u>Alumir</u> Material: <u>A</u> rce LSC ial: <u>CH-6</u> Sh Location	: <u>IM7/TC35</u> (2x); 3'x6'x ial: <u>IM7/TC</u> N: <u>Pathfindr</u> um S/N: <u>Pa</u> luminum S/ L/N: eath: Alumi	0 Solid Com 0.3" 350 S/N: <u>1</u> er thfinder N: <u>Pathfinder</u> num Location	<u>posite</u> 032 <i>0A 00</i> 4 21 S/N
Group: 1 T Panel: 27 fa Fest Article Fest Article Fest Article Fest Article Eest Article LSC Core Actual Le Accelerome Location	est No.: <u>04</u> abric plies w e Configurat e Drawing # b Drawing # b Drawing # c Drawing * c Drawing # c Drawing #	Date: 2-9 ith +45°/-45' 97M00200- 97M00202 97M00203- 97M00204- 97M00204- 97M00205 97M00205 97M00205 0R/FT Explo 4' CB Model: Location	5-2013 Test 2,0° (2x), +4 3,0° GRP I-TES' Material: <u>4</u> MOD Mat MOD-2-10 Shock Sou osive Materia 350C02 S/N 31340	Article Desc. 45°/-45°, 90° <u>T 1-5</u> Mater <u>Aluminum</u> S. erial: <u>Alumir</u> Material: <u>A</u> rce LSC ial: <u>CH-6</u> Sh Location <u>3</u>	: <u>IM7/TC35</u> (2x); 3'x6'x ial: <u>IM7/TC</u> N: <u>Pathfindr</u> um S/N: <u>Pa</u> luminum S/ L/N: <u>Pos</u> eath: <u>Alumi</u> S/N <b>3</b> /338	0 Solid Com 0.3" 350 S/N: <u>1</u> er thfinder N: Pathfinder aum Location <u>4</u>	<u>posite</u> 032 <i>0A004</i> 21 S/N 31331
Group: 1 T Panel: 27 fa Fest Article Fest Article Fest Article Fest Article Fest Article Est Article LSC Core Actual Le Accelerome Location	est No.: <u>04</u> abric plies w configurat brawing # brawing	Date: 2-9 ith +45°/-45° ion: <u>Haag</u> 97M00200- 97M00203- 97M00204- 97M00205 97M00205 97M00205 97M00205 07/FT Explo 4' CB Model: j Location	5-2013 Test c, 0° (2x), +4 GRP I-TES' Material: <u>/</u> MOD Mat MOD-2-10 Shock Sou osive Materia 350C02 S/N 31340 31333	Article Desc. 45°/-45°, 90° <u>T 1-5</u> Mater Aluminum S, erial: <u>Alumir</u> Material: <u>A</u> rce LSC ial: <u>CH-6</u> Sh Location <u>3</u> 7	: <u>IM7/TC35</u> (2x); 3'x6'x ial: <u>IM7/TC</u> N: <u>Pathfind</u> um S/N: <u>Pa</u> luminum S/N L/N: <i>post</i> eath: <u>Alumi</u> S/N <u>31338</u> 40292	0 Solid Com 0.3" 350 S/N: <u>1</u> er thfinder N: Pathfinder num Location <u>4</u> 8	<u>posite</u> 032 <i>0A004</i> er S/N 31331 31351
Group: 1 T Panel; 27 fa Pest Article Pest Article Pest Article Pest Article Pest Article Pest Article LSC Core Actual Le Accelerome Location 1 5 9	est No.: <u>04</u> abric plies w configurat brawing # brawing	Date: 2-9 ith +45°/-45° ion: <u>Hang</u> 97M00200- 97M00203- 97M00204- 97M00205 97M00205 97M00205 0R/FT Explo 4' CB Model: , Location 2 6	5-2013 Test c, 0° (2x), +4 GRP I-TES' Material: <u>/</u> MOD Material: <u>/</u> MOD Material: <u>/</u> Shock Sou osive Material 350C02 S/N 31340 31333 40295	Article Desc. <u>45°/-45°, 90°</u> <u>T 1-5</u> Mater <u>Aluminum</u> S/ erial: <u>Alumir</u> Material: <u>A</u> rce LSC ial: <u>CH-6</u> Sh Location <u>3</u> 7 11	: <u>IM7/TC35</u> (2x); 3'x6'x ial: <u>IM7/TC</u> ial: <u>IM7/TC</u> ial: <u>Pathfind</u> <u>um S/N: Pa</u> <u>um S/N: Pa</u> <u>um S/N: Pa</u> <u>t/N: 2000</u> S/N <u>31338</u> <u>40292</u> <u>3/334</u>	0 Solid Com 0.3" 350 S/N: <u>1</u> er thfinder N: <u>Pathfinder</u> N: <u>Pathfinder</u> M: <u>Cocation</u> 4 8 12	<u>5/N</u> 3/33) 3/35/ 40274
Group: 1 T Panel: 27 fa Fest Article Fest Article Fest Article Fest Article Fest Article Fest Article LSC Core Actual Le Accelerom Location 1 5 9 9 Aluminum Post-test vi	est No.: 04 abric plies w configurat Drawing #: Drawing #: Dr	Date: 2-9 ith +45°/-45° ion: Haag 97M00200- 97M00203- 97M00204- 97M00205 iR/FT Explo 4' CB Model: ; Location 2 10 reverance: (O cted observat	5-2013 Test c, 0° (2x), +2 Material: <u>/</u> MOD Mat MOD-2-10 Shock Sou osive Material 350C02 S/N 31340 31333 40295 (S)/ N0 ions: <u>/00</u> /	Article Desc. 45°/-45°, 90° <u>T 1-5</u> Mater <u>Aluminum</u> Solution Material: <u>Alumir</u> Material: <u>Alumir</u> Material: <u>Alumir</u> Interial: <u>CH-6</u> Stopped Location <u>3</u> 7 11 20	: <u>IM7/TC35</u> (2x); 3'x6'x ial: <u>IM7/TC</u> N: <u>Pathfind</u> um S/N: <u>Pathfind</u> um S/N: <u>Pathfind</u> Uminum S/ L/N: <u></u> eath: <u>Alumi</u> S/N <u>31338</u> <u>40292</u> <u>31334</u>	0 Solid Com 0.3" 350 S/N: <u>1</u> er thfinder N: Pathfinder N: Pathfinder (* num Location 4 8 13	<u>5/N</u> 3/33) 3/35/ 40274 1/439
Group: 1 T Panel: 27 fi Fest Article Fest Article Fest Article Fest Article Fest Article Fest Article LSC Core Actual Le Accelerom Location 1 5 9 Aluminum Post-test vi	est No.: 04 abric plies w configurat Drawing # Drawing # Drawing # Drawing # Drawing # Drawing # Drawing # Drawing # congth Used: eter MFG: P S/N 3/334 3/330 LSC panel s sually inspect	Date: 2-9 ith +45°/-45' 97M00200- 97M00202 97M00204- 97M00205 97M00205 97M00205 97M00205 0R/FT Explo 4' CB Model: CB	5-20/3 Test •, 0° (2x), +/ ·/ GRP I-TES Material: <u>/</u> MOD Mat MOD-2-10 Shock Sou osive Material 350C02 S/N 31340 31333 40295 (S)/ No ) ions: 100/	Article Desc. 45°/-45°, 90° <u>T 1-5</u> Mater <u>Aluminum</u> So erial: <u>Alumir</u> Material: <u>A</u> rce LSC ial: <u>CH-6</u> Sh Location <u>3</u> 7 11 2e	: <u>IM7/TC35</u> (2x); 3'x6'x ial: <u>IM7/TC</u> N: <u>Pathfind</u> um S/N: <u>Pa</u> luminum S/ L/N: <u></u> eath: <u>Alumi</u> S/N <u>31338</u> <u>40292</u> <u>3/334</u>	0 Solid Com 0.3" 350 S/N: <u>1</u> athfinder N: Pathfinder N: Pathfinder N: Pathfinder N: Pathfinder N: Pathfinder N: Pathfinder N: <u>13</u>	<u>5/N</u> 31331 31351 40 274 11439
Group: 1 T Panel: 27 fa Fest Article Fest Article Fest Article Fest Article Fest Article Fest Article Est Article LSC Core Actual Le Accelerom Location 1 5 9 Aluminum Post-test vi	est No.: 04 abric plies w e Configurat b Drawing # b Drawing # b Drawing # b Drawing # c Drawing # c Drawing # b Drawing # c Drawing # b Drawing # c Drawing # b Drawing # c Drawing # b Drawing # c	Date: 2-5 ith +45°/-45' 97M00200- 97M00202 97M00203- 97M00204- 97M00205 97M00205 97M00205 97M00205 97M00205 97M00205 97M00205 97M00205 97M00205 97M00204- 97M00205 97M000	5-20/3 Test °, 0° (2x), +4 Magentaliant MOD I-TES Mode I-TES	Article Desc. 45°/-45°, 90° <u>T 1-5</u> Mater <u>Aluminum</u> S. erial: <u>Alumir</u> Material: <u>A</u> rce LSC ial: <u>CH-6</u> Sh Location <u>3</u> 7 11 2e	: <u>IM7/TC35</u> (2x); 3'x6'x ial: <u>IM7/TC</u> N: <u>Pathfind</u> um S/N: <u>Pa</u> luminum S/ L/N: <u></u> eath: <u>Alumi</u> S/N 3/338 <u>40292</u> 3/336	0 Solid Com 0.3" 350 S/N: L r thfinder N: Pathfinder N: Pathfinder N: Pathfinder N: Pathfinder N: Pathfinder N: Pathfinder 13	<u>s/N</u> 3/33) 3/35/ 40 274 1/439

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<sup>–</sup> Co	mposite Materials	Subjected to Pv	roshock Lo	ading	
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	Additional Initial Tasts and Start of t	ET40 / Vibration, Acoustics, and S	hock Team		
	Materials Pyroshock Development To	st Date: 11/15/201	2 Page 15 c	of 15	
× 1		TEST DATA SHEFT	cont		
		TEST DATA SHEET	, cont.	8 5. D	
		1	D G G G A A A	110 5	
	Panel: 38 tane plies with +45°	$\frac{22-2019}{1-45^{\circ}, 0^{\circ}(2x), +45^{\circ}-45^{\circ}, 0^{\circ}(2x)}$	esc.: <u>IM7/1C350 So</u> 0° (2x): 3'x6'x0 2"	ond Composite	
	Test Article Configuration:	Hanging	The state of the s		
	Test Article Drawing #: 97M(	0200-GRP I-TEST 1-5 M	aterial: IM7/TC350	S/N: 0320A005	
	Test Article Drawing #: 97MC	0203-MOD Material: Alu	minum S/N: Pathfi	nder	
	Test Article Drawing #: 97M	00204-MOD-2-10 Material	: Aluminum S/N: ]	athfinder	
	Test Article Drawing #: <u>97M(</u> ISC Core Load: 22 GP/ET	10205 Shock Source L Explosive Material: CH-6	SC L/N: <u>none</u>		
	Actual Length Used: <b>U</b>	Explosive material. CH=0	Aluminun	1	
	Accelerometer MFG: PCB M	lodel: 350C02			
	Location S/N Loca	ation S/N Location	n S/N L	Scation S/N	2
	5 31328	31333 7	40292	8 31351	
	9 31330 10	40295 11	31336	12 40274	
	Aluminum LSC panel severar Post-test visually inspected of	nce: (Yes/No) pservations: none	L_	13 11431	
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	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: <b>1.0</b>		
Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading					



	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: <b>1.0</b>			
Title:						
<b>Empirical Model Development for Predicting Shock Response on</b>						
Composite Materials Subjected to Pyroshock Loading						

Equipment List						
Description	Manufacturer	Macel/Version	ID/Serial Number	Location	Cal Due Date	
Shock Analysis Tool	ET40	1.2.5			Verified 5/21/2009	
TEAM256	Nicolet	7.20			Verified 7/26/2012	
Torque Wrench (tests 1 7)	Snap On	QD3R250	M653410		2/22/2013	
Torque Wrench (tests 1-6)	Precision Instruments	44620	M658783	6	2/13/2013	
Forque Wrench (test 7)	Snap-On	TEC3FUA	M634527		3/10/2013	
Forque Wrench (tests 1,2)	Proto	6012	M644973		2/28/2013	
Forque Wrench (tests 3-7)	Proto	6012C	M659924	80	2/28/2013	
Power Supply	Encevco	2793	M652262	Channels 1-15	1/11/2013, 1/10/2014	
Data Acquisition System	Nicolet	BE256LE	2011288	Channels 2-8, 10-15	7/26/2013	
Channel 2	Nicolet	614CB	001-2	A1	7/26/2013	
Channel 3	Nicolet	614CB	001-3	Λ2	7/26/2013	
Channel 4	Nicolet	614CB	001-4	A3	7/26/2013	
Channel 5	Nicolet	614CB	002 1	A4	7/26/2013	
Channel 6	Nicolet	614CB	002-2	A5	7/26/2013	
Channel 7	Nicolet	614CB	002-3	Δ6	7/26/2013	
Channel 8	Nicolet	614CB	002-4	A7	7/26/2013	
Channel 10	Nicolet	614CB	003-2	A8	7/26/2013	
Channel 11	Nicolet	614CB	003-3	49	7/26/2013	
Channel 12	Nicolet	614CB	003-4	A10	7/26/2013	
Channel 13	Nicolet	614CB	004-1	A11	7/26/2013	
Channel 14	Nicolet	614CB	004-2	A12	7/26/2013	
Channel 15	Nicolet	614CB	004-3	A13	7/26/2013	
Arcelerometer	PCB	350802	11439	A13	9/5/2013	
Accelerometer	PCB	350002	31334	A1	9/7/2013	
Accelerometer	PCB	350002	31340	A2	9/7/2013	
Arrelemeter	PCB	350002	31238	A3	9/7/2013	
Arrelemmeter	PCB	350002	30712	04	9/7/2013	
Accelerometer	PCB	350002	31331	44	9/7/2013	
Accelerometer	PCB	350002	31328	45	9/7/2013	
Accelerometer	PCB	350002	31333	46	9/6/2013	
Screlerometer	PCB	250002	40292	47	9/7/2013	
accelerometer	DCP	250002	21251	40	0/6/2013	
scoelerometer	DCR	250002	21220	60	0/6/2013	
Accelerometer	DCB	250002	40265	A10	9/7/2013	
Accelerometer	DCR	350002	90290	411	0/7/2013	
Acceser ometer	Inco	350002	40374	412	9/7/2013	
ucelerometer	I-CB	1550C02	40274	1/12	9/7/2013	

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Title: Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading					





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#### Title: **Empirical Model Development for Predicting Shock Response on** 580 of 793 **Composite Materials Subjected to Pyroshock Loading**

IEST |

TEAM256 SETTINGS Date: 12-18-2014 Time: 14:56:05

Storage Path: C:\TEAMPRO Filename: Data File Number: 001 Settings Path: C:\TEAM256 Settings File: NES04.SET Export Path: D:\ATEST\NESC\_2\NEST04\RAWDAT~1 Export Format: FAMOS Average Blocks: No Between Cursors: No

#### BE1

Frequency A :	1.0000 MHz	Internal)	
Pre Trigger :	48000 Sampl	es (48.00	ms)
Segment A :	1000576 Sam	ples (1.0	(01 s)
Number of Blocks :	1		
<b>Digital Event Chann</b>	els: 0		
Analog Channels :			
Nr. Name Min	Max Units Co	Dup. Amr	). Filter Trigger
1 XXX 1 -55.56	55.56 kg's pk	GND +	33.00 k Off
2 NES_2 -28.85	28.85 kg's pk	DC +	33.00 k Basic
3 NES_3 -31.58	31.58 kg's pk	DC +	33.00 k Basic
4 NES 4 -30.00	30.00 kg's pk	DC +	33.00 k Basic
5 NES_5 -28.30	28.30 kg's pk	DC +	33.00 k Basic
6 NES_6 -28.04	28.04 kg's pk	DC +	33.00 k Basic
7 NES_7 -28.57	28.57 kg's pk	DC +	33.00 k Basic
8 NES_8 -28.30	28.30 kg's pk	DC +	33.00 k Off
9 XXX_9 -55.56	55.56 kg's pk	GND +	33.00 k Off
10 NES_10 -28.04	28.04 kg's pk	DC +	33.00 k Off
11 NES_11 -27.03	3 27.03 kg's pk	DC +	33.00 k Off
12 NES_12 -28.30	28.30 kg's pk	DC +	33.00 k Off
13 NES_13-27.78	3 27.78 kg's pk	DC +	33.00 k Off
14 NES_14 -27.27	27.27 kg's pk	DC +	33.00 k Off
15 NES_15 -8.929	8.929 kg's pk	DC +	33.00 k Off
16 ROC_16-55.56	6 55.56 kg's pk	DC +	33.00 k Off
17 ROC_17 -55.56	5 55.56 kg's pk	DC +	33.00 k Off
18 ROC_18-55.50	5 55.56 kg's pk	DC +	33.00 k Off
19 ROC_19-55.56	3 55.56 kg's pk	DC +	33.00 k Off
20 ROC_20-55.50	6 55.56 kg's pk	DC +	33.00 k Off
Engineering Units S	caling		
XXX_1 0 + 9.259	3 k * Voltage (g	's pk)	
NES_2 0+ 9.615	4 k * Voltage (g	's pk)	
NES_3 0+ 10.52	6 k * Voltage (g	's pk)	
NES_4 0+ 10.00	0 k * Voltage (g	's pk)	
NES_5 0 + 9.434	0 k * Voltage (g	's pk)	
NES_6 0 + 9.345	8 k * Voltage (g	's pk)	
NES_7 0+ 9.523	8 k * Voltage (g	's pk)	
NES_8 0 + 9.434	0 k * Voltage (g	's pk)	
XXX_9 0+ 9.259	3 k * Voltage (g	's pk)	
NES_10 0 + 9.34	58 k * Voltage (g	's pk)	

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Empir	Composite Materials Subjected to Pyroshock Loa	Iding	581 of 793

NES_11 0 + 9.0 NES_12 0 + 9.4 NES_13 0 + 9.2 NES_14 0 + 9.0 NES_15 0 + 8.9 ROC_16 0 + 9.1 ROC_17 0 + 9.1 ROC_18 0 + 9.1 ROC_19 0 + 9.1 ROC_20 0 + 9.1 ROC_20 0 + 9.1 Trigger Settings : Auto Trigger:	1090 k * 1340 k * 2593 k * 1999 k * 1286 k * 2593 k * 2593 k * 2593 k * 2593 k *	Voltag Voltag Voltag Voltag Voltag Voltag Voltag Voltag Voltag	e (g'; e (g'; e (g'; e (g'; e (g') (g') (g') (g') (g')	s pk s pk s pk s pk s pk s pk s pk s pk				
External Trigger:	Off							
Nr. Source Prin	n. Sec.	Units	Ho	Idof	F	Wic	lth	Events
1 XXX_1		256		1		1		
2 NES_2 507	.1	g's pk	256		1		1	
3 NES 3 493	.4	g's pk	256		1		1	
4 NES 4 468	.8	q's pk	256		1		1	
5 NES_5 497	.5	g's pk	256		1		1	
6 NES_6 492	.8	g's pk	256		1		1	
7 NES 7 502	.2	g's pk	256		1		1	
8 NES_8		256		1		1		
9 XXX_9		256		1		1		
10 NES 10		25	6	1		1		
11 NES_11		25	8	1		1		
12 NES_12		250	5	1		1		
13 NES_13		25	6	1		1		
14 NES_14		25	8	1		1		
15 NES_15		25	6	1		1		
16 ROC_16		25	6	1		1		
17 ROC_17		25	6	1		1		
18 ROC_18		25	6	1		1		
19 ROC_19		25	6	1		1		
20 ROC_20		25	6	1		1		



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Title:

### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

TEAM256 SETTINGS

Date: 12-18-2014 Time: 14:58:48

TESTS Z-7

Storage Path: C:\TEAMPRO Filename: Data File Number: 001 Settings Path: C:\TEAM256 Settings File: NES05.SET Export Path: D:\ATEST\NESC\_2\NEST05\RAWDAT~1 Export Format: FAMOS Average Blocks: No Between Cursors: No

BE1

Frequency A :	1.0000 MHz	(Internal)	
Pre Trigger :	48000 Sampl	es (48.00	ms)
Segment A :	1000576 San	noles (1.0	01 s)
Number of Blocks :	1		
<b>Digital Event Chann</b>	els: 0		
Analog Channels :			
Nr. Name Min	Max Units C	oup. Amp	. Filter Trigger
1 XXX 1 -55.56	55.56 kg's pk	GND +	33.00 k Off
2 NES_2 -28.85	28.85 kg's pk	DC +	33.00 k Basic
3 NES_3 -31.58	31.58 kg's pk	DC +	33.00 k Basic
4 NES_4 -30.00	30.00 kg's pk	DC +	33.00 k Basic
5 NES_5 -27.78	27.78 kg's pk	DC +	33.00 k Basic
6 NES_6 -28.04	28.04 kg's pk	DC +	33.00 k Basic
7 NES_7 -28.57	28.57 kg's pk	DC +	33.00 k Basic
8 NES_8 -28.30	28.30 kg's pk	DC +	33.00 k Off
9 XXX_9 -55.56	55.56 kg's pk	GND +	33.00 k Off
10 NES_10 -28.04	28.04 kg's pk	DC +	33.00 k Off
11 NES_11-27.03	27.03 kg's pk	DC +	33.00 k Off
12 NES_12 -28.30	28.30 kg's pk	DC +	33.00 k Off
13 NES_13 -27.78	27.78 kg's pk	DC +	33.00 k Off
14 NES_14 -27.27	27.27 kg's pk	DC +	33.00 k Off
15 NES_15 -8.929	8.929 kg's pk	DC +	33.00 k Off
16 ROC_16 -55.56	55.56 kg's pk	DC +	33.00 k Off
17 ROC_17 -55.56	55.56 kg's pk	DC +	33.00 k Off
18 ROC_18 -55.56	55.56 kg's pk	DC +	33.00 k Off
19 ROC_19-55.56	55.56 kg's pk	DC +	33.00 k Off
20 ROC_20 -55.56	6 55.56 kg's pk	DC +	33.00 k Off
Engineering Units So	caling		
XXX_1 0 + 9.259	3 k * Voltage (g	's pk)	
NES_2 0 + 9.615	4 k * Voltage (g	j's pk)	
NES_3 0 + 10.52	6 k * Voltage (g	i's pk)	
NES_4 0 + 10.00	0 k * Voltage (g	i's pk)	
NES_5 0 + 9.259	3 k * Voltage (g	's pk)	
NES_6 0 + 9.345	8 k * Voltage (g	j's pk)	
NES_7 0 + 9.523	8 k * Voltage (g	's pk)	
NES_8 0 + 9.434	0 k * Voltage (g	('s pk)	
XXX_9 0 + 9.259	3 k * Voltage (g	i's pk)	
NES_10 0 + 9.345	58 k * Voltage (	g's pk)	

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NES_11 0 + 9.0090 NES_12 0 + 9.4340 NES_13 0 + 9.2593 NES_14 0 + 9.0909 NES_15 0 + 8.9286 ROC_16 0 + 9.2593 ROC_17 0 + 9.2593 ROC_18 0 + 9.2593 ROC_19 0 + 9.2593	k * Voltage (g's k * Voltage (g' k * Voltage (g' k * Voltage (g' k * Voltage (g'	spk) spk) spk) spk) spk) spk) spk) spk)		
ROC_20 0 + 9.2593	к - vonage (g	ѕрк)		
Auto Triagon Off				
External Triager: Of	æ			
Nr Source Prim So	u ac ∣Inite Ho	Idoff	Width	Evente
1 XXX 1	256	1	1	C VOIILO
2 NES 2 507.1	g's pk 256	· 1	1	
3 NES 3 493.4	g's pk 256	1	1	
4 NES 4 468.8	g's pk 256	1	1	
5 NES_5 488.3	g's pk 256	1	1	
6 NES_6 492.8	g's pk 256	1	1	
7 NES_7 502.2	g's pk 256	1	1	
8 NES_8	256	1	1	
9 XXX_9	256	1	1	
10 NES_10	256	1	1	
11 NES_11	256	1	1	
12 NES_12	256	1	1	
13 NES_13	256	1	1	
14 NES_14	256	1	1	
15 NES_15	256	1	1	
16 ROC_16	256	1	1	
17 ROC_17	256	1	1	
18 ROC_18	256	1	1	
19 ROC_19	256	1	1	
20 ROC_20	256	1	1	



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### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812



January 20, 2015

Reply to Attn of: ET40-15-005

- TO: EV32/David O. Ordway
- FROM: ET40/Timothy C. Driskill
- SUBJECT: Composite Materials Pyroshock Development Test, Group 1 Tests 06 to 10, NESC-DEV-13-015

REF: ED73.1

The solid composite panel test articles were tested in the ET40 Pyrotechnic Shock Facility, building 4619, room 170. Testing was completed on May 29, 2013. The test was run in accordance with Test and Checkout Procedure, (TCP) NESC-DEV-13-015. Five tests were run on 5 different solid composite panels.

The accelerometer test setup is shown in appendix A of the TCP and in the photographs section of this report. No visual damage to the test articles was noted.

Please direct any questions or comments regarding this test to Mr. Craig Garrison at (256) 544-7197 or craig.garrison@nasa.gov.

Timotly C. Driskill Branch Chief Structural Dynamics Test Branch

Enclosure cc:

ET01/File (w/o enclosure) ET40/File ES22/David S. Parsons C105/Steve J. Gentz

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Test Matrix As Run						
Test Date Panel ID Test ID						
6	5/8/2013	0326A006	Group 1 - Test 06			
7	5/9/2013	0320A007	Group 1 - Test 07			
8	5/16/2013	0326A008	Group 1 - Test 08			
9	5/17/2013	0326A009	Group 1 - Test 09			
10	5/29/2013	0326A0010	Group 1 - Test 10			



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# Accelerometers

	Test 6		Test 7 & 9		Test 8 & 10	
Location			Set 1 Accels		Set 2 Accels	
	Model	Serial	Model	Serial	Model	Serial
1	350C02	31334	350C02	31334	3 50 D 02	43026
2	350C02	31340	3 50D 02	43026	350C02	31340
3	350C02	31338	350D02	43028	350C02	31338
4	350C02	31331	350C02	31331	350D02	43028
5	350C02	31328	350C02	31328	3 50 D 0 2	43029
6	350C02	31333	350D02	43029	350C02	31333
7	350C02	40292	350D02	43179	350C02	40292
8	350C02	31351	350C02	31351	350D02	43179
9	350C02	31330	350C02	31330	3 50 D 02	43180
10	350C02	40295	350D02	43180	350C02	40295
11	350C02	31336	350D02	43181	350C02	31336
12	350C02	40274	350C02	40274	350D02	43181
13	3.50B02	11439	350B02	11439	350B02	11439

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Typical Test Setup – Front of Panel Accelerometer Locations

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Pipical Test Setup – Front of Panel Accelerometer Locations

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Tyrical Test Setup – Front of Panel Accelerometer Locations

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	George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812	C-DEV-13-015 3/14/2013			
	TEST AND CHECK-OUT PROCED	DURE			
	ET40 / VIBRATION, ACOUSTICS, SHOCK TEAM	AND			
	COMPOSITE MATERIA	ALS			

PYROSHOCK DEVELOPMENT TEST Group I – Tests 6 to 10

> This Procedure Describes Safety Critical Operations

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NESC-DEV-13-015       Revision: Baseline Group 1 - Tests 6 to 10         PREPARED BY:       Marcaig Dervisor       3/18/2013         PREPARED BY:       Marcaig Dervisor       3/18/2013         DATE: 3/14/2013       Page 1 of 15         PREPARED BY:       3/18/2013         John Craig Garrison / ET40       Date         Test Engineer         APPROVED BY:       Addition of the first formation of the		ET40 / Vibrati	on, Acoustics, and Shock Te	am
Date     3/18/2013       PREPARED BY:     John Craig Garrison / ET40 Test Engineer     3/18/2013 Date       APPROVED BY:     Athy Lowen / ET40 Deputy Branch Chief Structural Dynamics Test Branch     3/18/2013 Date       APPROVED BY:     DAVID ORDWAY     Back Sciences and Sci	Composite Materials I	Pyroshock Development Test	NESC-DEV-13-015	Revision: Baseline
PREPARED BY: <u>Jun Craig Dominen</u> <u>3/18/2013</u> John Craig Garrison / ET40 Test Engineer APPROVED BY: <u>Mathy Juny</u> <u>3/18/2013</u> Kathy L. Owen / ET40 Deputy Branch Chief Structural Dynamics Test Branch APPROVED BY: <u>DAVID ORDWAY</u> Methy end Categories and an analysis of the second structures and the second st	Group I – Tests 6 10 I		Date: 3/14/2013	rage 1 01 13
Test Engineer         APPROVED BY: <u>Kathy L. Owen / ET40</u> 3/18/2013         Deputy Branch Chief         Structural Dynamics Test Branch         APPROVED BY: DAVID ORDWAY         David Ordway / EV32       03/18/2013         David Ordway / EV32       Date         Aerospace Engineer, Pyrotechnics         Structural & Mechanical Design Branch         Test Requester         APPROVED BY: David Parsons / ES22         David Parsons / ES22       Date         Structural Dynamics         Mark Burger Baranch         Test Requester         APPROVED BY: David Parsons / ES22         Date         Structural Dynamics         Mechanical, Thermal and Life Support Branch	PREPARED BY:	John Craig Garrison / E	Denier T40	<u>3/18/2013</u> Date
APPROVED BY: David Ordway / EV32 Aerospace Engineer, Pyrotechnics Structural & Mechanical Design Branch Test Requester APPROVED BY: David Parsons / ES22 David Parsons / ES22 Structural Dynamics Mechanical, Thermal and Life Support Branch	APPROVED BY:	Test Engineer <u>Rathy LOw</u> Kathy L. Owen / ET40 Deputy Branch Chief Structural Dynamics Te	est Branch	<u>3/18/2013</u> Date
APPROVED BY: David Darsons / ES22 Structural Dynamics Mechanical, Thermal and Life Support Branch	APPROVED BY:	DAVID ORDWA David Ordway / EV32 Aerospace Engineer, Py Structural & Mechanica	Pupulati represente DAVID ORDANAY Discussion of the Control of Con	03/18/2013 Date
	APPROVED BY:	David Jarson David Parsons / ES22 Structural Dynamics Mechanical, Thermal au	nd Life Support Brancl	<u>3/18/2013</u> Date

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### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

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Composite Materials Pyroshock Development Test	NESC-DEV-13-015	Revision: Baseline	
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#### 1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this procedure is to define the steps necessary to perform a pyrotechnic shock test in the Pyrotechnic Shock Facility in Building 4619 using pyrotechnic devices.

Test Matrix Test Articles: <u>3'x6' solid composite panel with LSC plate and LSC backing plate.</u> The 5 test articles of the test matrix are described in test plan, Table III, Group I, tests 6 to 10.

Program: <u>NESC</u> Type of Test: <u>Pyrotechnic Shock Development Test</u> Test Purpose: <u>To capture the acceleration time histories for group I – Test 6 to 10 tests</u>.

The Pyrotechnic Shock Facility is located in Rooms 170, 170A and 170B of Building 4619. Room 170A is designated as the Control Room. The area between Room 169 and 170 is used for storage of secondary pyrotechnic devices. Room 170B is used for storage of initiators. All detonation of pyrotechnic devices will be in Room 170.

1.2 SCOPE

This document contains the steps and/or references the procedure to conduct the test.

2.0 <u>SAFETY</u>

Follow all emergency and safety requirements specified in ET01-DYN-SHK-FOP-001.

2.1 Responsibilities

The Test Engineer will be responsible for all activities occurring in the hazardous test area and for the safety of personnel involved in the test activities. It is the responsibility of each individual in a test program to fully comply with the requirements of this document and to report any individual not complying. Failure to do so could lead to serious personnel injuries or death.

- 3.0 TEST REQUIREMENTS AND INFORMATION
- 3.1 DOCUMENTS
- 3.1.1 APPLICABLE DOCUMENTS

Test Requirements: Pyroshock Response Characterization of Composite Materials Test Plan Revision A, NESC Task # TI-12-0783 (SLS ADO-21), 11/8/2012

Test Procedure: ET01-DYN-SHK-FOP-001 Pyrotechnic Shock Tests



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- Compos	ite Materials Pyroshoek Development Test	NESC-DEV-13-015	Revision: Baseline
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	97M00200-GRP I-TEST 6-10 C 97M00202 LSC BACKING PL 97M00203-MOD LSC PLATE, 97M00204-MOD-2-10 LSC SH 97M00204-MOD-2-22 LSC SH	COMPOSITE TEST P. ATE, COMPOSITE T COMPOSITE TEST IM, COMPOSITE TE IM, COMPOSITE TE	ANEL, GROUP I, TEST #6-#10 EST PANEL PATHFINDER PANEL PATHFINDER IST PANEL 10 GPF LSC IST PANEL 22 GPF LSC
3.1.2	REFERENCED DOCUMENTS		
	ET01-DYN-OWI-001 Docume	entation Control	
	ET01-DYN-OWI-002 Test Op	eration Procedure Prej	paration and Change Control
3.2	TEST INFORMATION		
3.2.1	The instrumentation locations are documents and appendix A for the	given in the drawings e test.	listed in the applicable
3.2.2	Pyrotechnic shock tests may be per configuration directed by the test	erformed on the test ar requester.	ticle in the order and
3.2.3	The shock test will be performed	on a room temperature	e test article.
3.3	TEST REQUIREMENTS		
3.3.1	The Test Engineer will be in char,	ge of all test preparation	ons and activities.
3.3.2	All activities will be coordinated	with the Test Engineer	
3.3.3	All changes to the procedure will	be coordinated with th	ne Test Engineer.
3.3.4	The development test articles will by the test requester. The test arti	be tested with pyrotec cle information will b	chnic shock test runs as directed e recorded in this TCP.
4.0	TEST DATA		
	<ul> <li>a. The test data includes a time millisecond or longer interest.</li> <li>b. The second plot is a Shoct 1/6 octave shock spectrum</li> </ul>	me history of the real rval and the units are k Response Spectrum n analyzer. The SRS i lertz. The SRS units a	time shock recorded over a 20 g's peak versus time. (SRS) using 5% damping and a s computed over the frequency re g's versus frequency.



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Composite Materials Pyroshock Development Test Group I – Tests 6 to 10	NESC-DEV-13-015 Date: 3/14/2013	Revision: Baseline Page 4 of 15
5.0 TEST SETUP	Sate Stratu	118640110
5.1 TEST ARTICLE AND SHOCK	K PLATE SETUP	
<ul> <li>a. The test setup is shown i</li> <li>b. Suspend the shock plate</li> <li>c. Suspend I accelerometer</li> <li>d. At the start of each test of</li> </ul>	in Appendix A. from ceiling using str r near the plate. Conn day, complete ET01-D	aps or cables and shackles. ect to data system for recording. YN-SHK-FOP-001, section 6.
6.0 <u>TEST OPERATION</u>		
6.1 COMPOSITE MATERIALS P	YROSHOCK DEV. T	EST
a. Record and verify the test in	nformation below and	in appendix C.
Group I - Test No.; <u>6</u> Date: <u>Composite Panel, see apper</u> Shock Source LSC Core LA Actual Length Used: <u>4</u>	: <u>5-8-2013</u> Test Arti idix B for ply layup, 3 oad: <u>22 GR/FT</u> Explo	icle Desc.: <u>IM7/ TC350 Solid</u> 'x6'x0.2" PID# <b>0326 A 006</b> osive Material: <u>CH-6</u> Sheath: <u>Al</u>
<ul> <li>b. Verify that the shock plate i</li> <li>c. Instrument shock plate. Each Torque wrench: <u>M658 79</u></li> <li>d. LSC plate &amp; LSC backer pl Torque wrench: <u>M650 797</u></li> <li>e. D-ring ½-13 bolt's torque to Torque wrench: <u>M650 7979</u></li> <li>f. Photograph the locations an g. Perform the test per section h. Photograph the test setup af visually inspected observati i. Verify that the test run has been been been been been been been bee</li></ul>	is ready for testing per chaccelerometer's tor 13 Torque value: ate to Test Panel $\frac{1}{2}$ Torque value: Torque value: $55$ D o 28 ft-lb. Torque value: $28$ do orientations of all at s 7, 8, and 9 of ET01- fter the test. Photograpions under this test number been completed.	section 5.1. que will be to $30\pm5$ inlb. <u>30</u> Due: <u>10-4-2013</u> Cal.: <u>4-4-2013</u> bolt's torque to $55\pm5$ ft-lb. rue: <u>9-4-2013</u> Cal: <u>3-4-2013</u> _ Due: <u>9-4-13</u> Cal: <u>3-4-2013</u> ccelerometers. DYN-SHK-FOP-001. bh and document any post-test mber in appendix C. <u>400</u> <u>5-9-201</u>



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Composit	e Materials Pyroshock Development Tes	E NESC-DEV-13-015	Revision: Baseline	
Group I -	- 1 ests 6 to 10	Date: 3/14/2013	Page 5 of 15	
6.2	COMPOSITE MATERIALS	PYROSHOCK DEV. 7	TEST	
	a. Record and verify the test	information below and	in appendix C.	
		F9200		
	Group I - Test No.: 7 Dat Composite Papel see ann	endix B for ply lavan	B'v6'v0 2" PID# 1732	BAAD7
	Shock Source LSC Core	Load: 22 GR/FT Expl	osive Material: CH-6	Sheath: Al
	Actual Length Used: 4	,		
	b. Verify that the shock plate	e is ready for testing pe	r section 5.1.	
	c. Instrument shock plate. E	Each accelerometer's to	rque will be to 30±5 in.	-lb.
	Torque wrench: MI458	783 Torque value:	30 Due: 10-4-2013 Ca	1.:4-4-2013
	d. LSC plate & LSC backer	plate to Test Panel 1/2-1	3 bolt's torque to $55\pm5$	ft-lb.
	D ring 1/ 12 baltis	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Jue: 7-4-20 Cal: 3-4-2	<i>w</i> 13
	C. D-ring /2-13 boit s torque	a Torque velue: 26	Due 9-4 17 Col: 1	4. 2412
	f Photograph the locations	and orientations of all a	ccelerometers	
	g. Perform the test per section	ons 7, 8, and 9 of ET01-	DYN-SHK-FOP-001.	
	h. Photograph the test setup	after the test. Photogra	ph and document any p	oost-test
	visually inspected observa	ations under this test nu	mber in appendix C.	
	i. Verify that the test run ha	s been completed.		Vica
				5-9-201
6.3	START OF THE COMPOSI	TE MATERIALS PYR	OSHOCK DEV. TEST	
	a Danand and unrify the text	information balancend	in annually C	
	a. Record and verify the test	information below and	in appendix C.	
	Group I - Test No.: 8 Dat	te: 5-16-2013 Test Art	icle Desc.: IM7/ TC35	0 Solid
	Composite Panel, see app	endix B for ply layup, 3	3'x6'x0.3" PID# Ø32	6 A008
	Shock Source LSC Core	Load: 10 GR/FT Expl	osive Material: <u>RDX</u>	Sheath: Al
	Actual Length Used: 4			
	b. Verify that the shock plate	e is ready for testing per	r section 5.1.	
	c. Instrument shock plate. E	ach accelerometer's tor	rque will be to 30±5 in.	-lb.
	Torque wrench: M6587	83 Torque value:	30 Due: 10-4-2013 Ca	1 .: 4-4-2013
	d. LSC plate & LSC backer	plate to Test Panel 1/2-1.	3 bolt's torque to 55±5	ft-lb.
	Torque wrench: M65839	16 Torque value: 55 D	Due: 10-8-2013Cal: 4-8-2	2013
	e. D-ring 1/2-13 bolt's torque	to 28 ft-lb.	D	
	Photoe wrench: 106 58 3	16 Torque value: 28	Due: 10-8-13 Cal: 4-1	2-1012
	1. Photograph the locations a	and orientations of all a	DVN-SHK FOR 001	
	b Photograph the test setur	after the test Photogra	ph and document any r	nost-test
	visually inspected observa	ations under this test nu	mber in appendix C	iost-test
	i. Verify that the test run has	s been completed.	moer in appendix 0.	VACA
				5-11-201
				5-10-00



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and the second sec	ite Materials Pyroshock Development Test	NESC-DEV-13-015	Revision: Baseline
Group	- 1933 0 10 10	Date. 3/14/2013	1 1 1 2 0 01 15
6.4	START OF THE COMPOSITE	MATERIALS PYRC	SHOCK DEV. TEST
	a. Record and verify the test in	formation below and	in appendix C.
	Group I - Test No : 9 Date:	5-17-2013 Test Arti	cle Desc : IM7/ TC350 Solid
	Composite Panel, see appen	dix B for ply layup, 3	x6'x0.3" PID# @ 326 A009
	Shock Source LSC Core Lo	oad: 22 GR/FT Explo	sive Material: CH-6 Sheath: Al
	Actual Length Used:	l 	and the second s
	b. Verify that the shock plate i	s ready for testing per	section 5.1.
	c. Instrument shock plate. Ead	ch accelerometer's tore	que will be to 30±5 inlb.
	Torque wrench: M65878	3 Torque value: 3	Due: (0-4-2013 Cal.: 4-4-20
	d. LSC plate & LSC backer pl	ate to Test Panel 1/2-13	bolt's torque to 55±5 ft-lb.
	Torque wrench: M658394	Torque value: 55 D	ue: 10-8-2013 Cal: 4-8-2013
	e. D-ring 1/2-13 bolt's torque to	28 ft-lb.	D
	Torque wrench: M658 376	Torque value: 28	Due: <u>10-8-13</u> Cal: 4-8-2013
	f. Photograph the locations an	d orientations of all ac	Content of the second s
	g. Perform the test per section	s /, 8, and 9 of E101-1	b and document any post test
	n. Photograph the test setup at visually inspected observati	ons under this test nur	nber in appendix C
	i Verify that the test run has h	een completed.	VIL
			5-17-
6.5	START OF THE COMPOSITE	MATERIALS PYRC	SHOCK DEV. TEST
	j. Record and verify the test in	nformation below and	in appendix C.
		5-19 2017 Test 4-	tala Dara a DAT/ TC250 Salid
	1 7 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		THE PROPERTY OF THE STATES AND A STATES
	Composite Papel see appen	div D for ply lavup 3	26'20 2" PID# 1230 AD 10
	Composite Panel, see appen Shock Source, LSC Core L	dix B for ply layup, 3	x6'x0.2" PID# 0326A010
	Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: 4	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo	$\frac{1}{2} \frac{1}{2} \frac{1}$
	Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u>	dix B for ply layup, 3 pad: <u>10 GR/FT</u> Explo	x6'x0.2" PID# Ø326AØ10 sive Material: <u>RDX</u> Sheath: <u>A1</u>
	Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u> k. Verify that the shock plate i	dix B for ply layup, 3 pad: <u>10 GR/FT</u> Explo	x6'x0.2" PID# Ø326AØ10 sive Material: RDX Sheath: Al section 5.1. aue will be to 30±5 in -lb.
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>I. Instrument shock plate. Eac Torque wrench: <i>m4,58</i> 23</li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo s ready for testing per ch accelerometer's torc <b>3</b> Torque value: 3	section 5.1. que will be to $30\pm 5$ inIb. Desire Desc. <u>INT TOPS 5010</u> $(x_6'x_0.2")$ PID# $(2326AQ IQ)$ Solution 5.1. Solution 5.1. Due: $10-4-2013$ Cal.: $4-4-20$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>Instrument shock plate. Eac Torque wrench: <u>M658 78</u></li> <li>m. LSC plate &amp; LSC backer plate</li> </ul>	dix B for ply layup, 3' bad: <u>10 GR/FT</u> Explo s ready for testing per ch accelerometer's torce <u>73</u> Torque value: <u>3</u> ate to Test Panel ½-13	section 5.1. 20 Due: $10-4-2013$ Cal.: $4-4-20bolt's torque to 55±5 ft-lb.$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used:4</li> <li>k. Verify that the shock plate i</li> <li>Instrument shock plate. Eac Torque wrench: <u>M&amp;58 78</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u>M&amp;58 396</u></li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo s ready for testing per ch accelerometer's toro <u>73</u> Torque value: <u>3</u> ate to Test Panel ½-13 Torque value: <u>55</u> D	section 5.1. $326 \times 0.2^{\circ}$ PID# $2326 A 2 1 0^{\circ}$ sive Material: RDX Sheath: Al section 5.1. que will be to $30\pm5$ inlb. $20^{\circ}$ Due: $10-4-2013$ Cal.: $4-4-20$ bolt's torque to $55\pm5$ ft-lb. ue: $10-9-2013$ Cal: $4-8-2013$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>Instrument shock plate. Eac Torque wrench: <u><i>M</i>658 78</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u><i>M</i>658 396</u></li> <li>n. D-ring ½-13 bolt's torque to</li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo bad: <u>10 GR/FT</u> Explo bacelerometer's toro <u>73</u> Torque value: <u>3</u> ate to Test Panel ½-13 Torque value: <u>55</u> D b 28 ft-lb.	section 5.1. $326 \times 0.2^{\circ}$ PID# $2326 A 2 1 0$ source Material: RDX Sheath: Al section 5.1. que will be to $30\pm 5$ inlb. 20 Due: $10-4-2013$ Cal.: $4-4-20bolt's torque to 55\pm 5 ft-lb.ue: 10-9-2013 Cal: 4-9-2013$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>Instrument shock plate. Eac Torque wrench: <u>M658 376</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u>M658 396</u></li> <li>n. D-ring ½-13 bolt's torque to Torque wrench: <u>M658396</u></li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo s ready for testing per ch accelerometer's tord <u>73</u> Torque value: <u>3</u> ate to Test Panel ½-13 Torque value: <u>55</u> D 28 ft-lb. Torque value: <u>28</u>	Section 5.1. que will be to $30\pm 5$ inlb. bolt's torque to $55\pm 5$ ft-lb. ue: $10-4-2o_{13}$ Cal: $4-4-2o_{13}$ Due: $10-4-2o_{13}$ Cal: $4-4-2o_{13}$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>Instrument shock plate. Eac Torque wrench: <u>M658 34</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u>M658 396</u></li> <li>n. D-ring ½-13 bolt's torque to Torque wrench: <u>M658396</u></li> <li>o. Photograph the locations an</li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo s ready for testing per chaccelerometer's tord <u>73</u> Torque value: <u>3</u> ate to Test Panel ½-13 Torque value: <u>55</u> D 28 ft-lb. Torque value: <u>28</u> d orientations of all ac	Section 5.1. $2^{10} - 2^{10$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>I. Instrument shock plate. Eac Torque wrench: <u><i>M</i>658 34</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u><i>M</i>658 394</u></li> <li>n. D-ring ½-13 bolt's torque to Torque wrench: <u><i>M</i>658394</u></li> <li>O. Photograph the locations an p. Perform the test per sections</li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo s ready for testing per chaccelerometer's tord <u>7</u> ate to Test Panel ½-13 Torque value: <u>5</u> 28 ft-lb. Torque value: <u>28</u> d orientations of all ac s 7, 8, and 9 of ET01-I	Section 5.1. $2^{10} - 2^{10$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>I. Instrument shock plate. Eac Torque wrench: <u><i>M</i>658 34</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u><i>M</i>658 346</u></li> <li>n. D-ring ½-13 bolt's torque to Torque wrench: <u><i>M</i>658396</u></li> <li>o. Photograph the locations an p. Perform the test per sections q. Photograph the test setup af</li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo s ready for testing per chaccelerometer's tord <u>7</u> ate to Test Panel ½-13 Torque value: <u>5</u> 0 28 ft-lb. Torque value: <u>28</u> d orientations of all ac s 7, 8, and 9 of ET01-I ter the test. Photograp	section 5.1. $2 \times 6^{-} \times 0.2^{\circ}$ PID# $2 \times 32 \times 42^{\circ} 1 \circ$ psive Material: <u>RDX</u> Sheath: <u>Al</u> section 5.1. $2 \times 0.4^{-} \times 0.3^{\circ}$ Sheath: <u>Al</u> $2 \times 0.4^{\circ} \times 0.3^{\circ}$ Sheath: <u>Al</u> $2 \times 0.3^{\circ} \times 0.3^{\circ} \times 0.3^{\circ}$ Sheath: <u>Al</u> $2 \times 0.3^{\circ} \times 0.3^{\circ$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>l. Instrument shock plate. Eac Torque wrench: <u>M&amp;58.346</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u>M&amp;58.376</u></li> <li>n. D-ring ½-13 bolt's torque to Torque wrench: <u>M&amp;58396</u></li> <li>o. Photograph the locations an p. Perform the test per section: q. Photograph the test setup af visually inspected observati</li> <li>r. Verify that the test run has</li> </ul>	dix B for ply layup, 3 bad: <u>10 GR/FT</u> Explo s ready for testing per th accelerometer's tors <u>73</u> Torque value: <u>33</u> ate to Test Panel ½-13 Torque value: <u>55</u> D b 28 ft-lb. Torque value: <u>28</u> d orientations of all ac s 7, 8, and 9 of ET01-I ter the test. Photograp ons under this test num been completed.	Section 5.1. $2 \times 6^{-} \times 0.2^{\circ}$ PID# $2 \times 2 \times 4 \times 10^{\circ}$ provide Material: RDX Sheath: All section 5.1. $2 \times 0.4 \times 0.30 \pm 5$ inlb. $2 \times 0.4 \times 0.4 \times 0.30 \pm 5$ inlb. $2 \times 0.4 \times 0.$
	<ul> <li>Composite Panel, see appen Shock Source LSC Core Lo Actual Length Used: <u>4</u></li> <li>k. Verify that the shock plate i</li> <li>l. Instrument shock plate. Eac Torque wrench: <u>M&amp;58.346</u></li> <li>m. LSC plate &amp; LSC backer pl Torque wrench: <u>M&amp;58.376</u></li> <li>n. D-ring ½-13 bolt's torque to Torque wrench: <u>M&amp;58.376</u></li> <li>o. Photograph the locations an p. Perform the test per sections q. Photograph the test setup af visually inspected observati r. Verify that the test run has be</li> </ul>	dix B for ply layup, 3 dix B for ply layup, 3 add: <u>10 GR/FT</u> Explored s ready for testing per chaccelerometer's tored ate to Test Panel ½-13 Torque value: <u>55</u> D b 28 ft-lb. Torque value: <u>28</u> d orientations of all act s 7, 8, and 9 of ET01-1 ter the test. Photograp ons under this test number of completed.	section 5.1. $2 \times 6^{-} \times 0.2^{\circ}$ PID# $O 32 (A O I O)$ soive Material: <u>RDX</u> Sheath: <u>Al</u> section 5.1. $2 \times 0.4^{-} \times 0.30 \pm 5$ inlb. $2 \times 0.4^{-} \times 0.4^{-}$



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#### **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

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ET40 / Vibrati	on, Acoustics, and Shock Te	am	
Composite Materials Pyroshock Development Test	NESC-DEV-13-015	Revision: Baseline	
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#### 7.0 RECORDS

The test report for this test will control and include the following records:

- a. This "AS RUN" TCP.
- b. The test data and the equipment list.

The test report is controlled by ET01-DYN-OWI-001, Documentation Control. However, due to the ITAR designation for the test results, the test report and data will be securely controlled. The test report will be available no later than 30 days after test completion. The Test Requirements will not be included in this TCP or in the report, but a copy may be filed with the report for future reference.

#### 8.0 TOOLS, EQUIPMENT, AND MATERIALS

The equipment used during this test will be listed in a table as part of the test report. The list will include test equipment calibration due dates.

#### 9.0 PERSONNEL TRAINING AND CERTIFICATION

Personnel certified as Propellant and Explosive Handler are required to conduct this test.

#### POST-TEST VERIFICATION

The Test and Check-out Procedure NESC-DEV-13-015 has been satisfactorily completed and documented.

Test Engineer / ET40

5/29/2013 Date

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	TEST SETUP	
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ET40 / Vibrat	ion, Acoustics, and Shock Te	am
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TEST DATA SHEETGroup: 1 - Test No.: 6 Date: $5 \cdot 9 \cdot 2 \cdot 13$ Test Article Desc.: $M7/TC350$ Solid Composite Pan see appendix B for ply layup, $3^{\circ}x6^{\circ}x0.2^{\circ}$ Test Article Configuration: hangingTest Article Drawing #: 97M00200-GRP I-TEST 6 Material: $M7/TC350$ PID# 0324 A000Test Article Drawing #: 97M00202-MOD Material: Aluminum S/N: PathfinderTest Article Drawing #: 97M00204-MOD-2-22Material: Aluminum S/N: PathfinderTest Article Drawing #: 97M00204-MOD-2-22Material: Aluminum S/N: PathfinderShock Source: LSC L/N: nene LSC Core Load: 22 GR/FTExplosive Material: CH-6Sheath: Aluminum Actual Length Used: $4^{1}$ Accelerometer MFG: PCB Model: $30XXX$ Loc. Model S/N Loc. Model S/N Loc. Model S/NLoc. Model S/N Loc. Model S/N Loc. Model S/NAcc. Model S/N Loc. Model S/N Loc. Model S/N Loc. Model S/NAccelerometer MFG: PCB Model: $30XXX$ Loc. Model S/N Loc.Aluminum LSC panel severance: (SeV No)Post-test visually inspected observations: $N_{2}$ least article Drawing #: 97M00200-GRP I-TEST 7 Material: IM7/TC350 Solid Composite Pan see appendix B for ply layup, $3x6'x0.2^{o}$ Test Article Drawing #: 97M00200-GRP I-TEST 7 Material: IM7/TC350 PID# 032.04.000Test Article Drawing #: 97M00200-GRP I-TEST 7 Material: IM7/TC350 PID# 032.04.000Test Article Drawing #: 97M	Group	o I - Tests 6	to 10	.K Dever	opinent res	Date:	3/14/20	113	Page	13 of 1	5	
Group: [- Test No.: 6 Date: $5 \cdot 9 \cdot 20 \cdot 3$ Test Article Desc.: IM7/TC350 Solid Composite Pan see appendix B for ply lavup, 3'x6'x0.2" Test Article Configuration: hanging Test Article Drawing #: 97M00200-GRP I-TEST 6 Material: [M7/TC350 PID# $03.24.400$ Test Article Drawing #: 97M00203-MOD Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00203-MOD Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00204-MOD-2-22 Material: Aluminum S/N: Pathfinder Shock Source: LSC L/N: none LSC Core Load: 22 GR/FT Explosive Material: CH-6 Sheath: Aluminum Actual Length Used: $4^{I}$ Accelerometer MFG: PCB Model: $350XXX$ Loc. Model S/N Loc. Model S/N Loc. Model S/N Loc. Model S/ 1 C02 $3/324$ 6 C02 $3/33$ 7 C02 $40272$ 8 C02 $3/33$ 9 C02 $3/320$ 10 C02 $40275$ 11 C02 $3/334$ 4 C02 $3/23$ 9 C02 $3/320$ 10 C02 $40275$ 11 C02 $3/334$ 2 C02 $40272$ 7 Best Article Configuration: hanging Test Article Drawing #: 97M00200-GRP I-TEST 7 Material: [M7/TC350 Solid Composite Pan see appendix B for ply lavup, 3'x6'x0.2" Test Article Drawing #: 97M00200-GRP I-TEST 7 Material: [M7/TC350 PID# $03.20/400$ Test Article Drawing #: 97M00203-MOD Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00204-MOD-2-22 Material: Aluminum S/N: Pathfinder Test Article Drawing #: 97M00204-MOD-2-22 Material: Aluminum S/N: Pathfinder Sheeks Source: LSC L/N: none LSC Core Load: 22 GR/FT Explosive Material: CH-6 Sheath: Aluminum Actual Length Used: $4^{I}$ Accelerometer MFG: PCB Model: $50XXX$ Loc. Model S/N Loc. Model S/N Loc. Model S/N Loc. Model S/ 1 C02 $3/327$ 6 D02 $42029$ 7 D02 $43/379$ 8 C02 $3/22$ 9 C02 $3/327$ 6 D02 $42029$ 7 D02 $43/379$ 8 C02 $3/22$ 9 C02 $3/327$ 6 D02 $42029$ 7 D02 $43/379$ 8 C02 $3/22$ 9 C02 $3/327$ 6 D02 $42029$ 7					TES	ST DAT	TA SH	EET				
Loc.       Model       S/N       Model	Grou see a Test Test Test Test Test Shoc Shea Acce	p: <u>I</u> - Tes <u>ppendix I</u> Article C Article D Article D Article D Article D k Source: th: <u>Alum</u> elerometer	t No.: <u>6</u> E <u>3 for ply l</u> onfiguration rawing #: rawing #: rawing #: LSC L/N num Action MFG: <u>PG</u>	Date: <u>5</u> ayup, 3 on: har <u>97M00</u> <u>97M00</u> <u>97M00</u> : <u>097</u> tual Le <u>CB</u> Mc	<b>5 8 - 2013</b> <b>1 x</b> 6 <b>x</b> 0.2 <b>1 ng</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b> <b>0200-GR</b>	P I-TEST aterial: <u>A</u> D Mate D-2-22 SC Core I d: <u>4'</u> XXX	ticle D <u>6</u> Ma <u>luminu</u> rial: <u>A</u> Materi Load: <u>2</u>	terial: <u>IM7</u> m S/N: J luminum al: <u>Alum</u> 2 <u>GR/FT</u>	7/TC350 9 17/TC350 Pathfinde S/N: Pathfinde S/N: Pathfinde S/N: Pathfinde S/N: Pathfinde S/N: Pathfinde S/N: Pathfinde S/N: Pathfinde S/N: Pathfinde	Solid ( PID# T thfinde N: <u>Patl</u> ive Ma	Composit Ø3267 er nfinder tterial: <u>Cl</u>	<u>e Panel.</u> 4006
1       C02 $3/334$ 2       C02 $3/340$ 3       C02 $3/338$ 4       C02 $7/15$ 5       C02 $3/328$ 6       C02 $3/333$ 7       C02 $40272$ 8       C02 $3/33$ 9       C02 $3/330$ 10       C02 $40275$ 11       C02 $3/334$ 12       C02 $40272$ 8       C02 $3/33$ 9       C02 $3/330$ 10       C02 $40275$ 11       C02 $3/334$ 12       C02 $40272$ 8       C02 $3/33$ 12       C02 $40272$ 8       C02 $3/33$ 12       C02 $40272$ 8       C02 $40272$ 13       B02 $1/1437$ 4       C02 $3/334$ 12       C02 $40272$ 7       8       C02 $3/334$ 12       C02 $40272$ 8       C02 $3/334$ 12       C02 $40272$ 7       S       S       S       C02 $40272$ S       S       S       S       S       S       S       S       S	Loc.	Model	S/N	Loc.	Model	S/N	Loc.	Model	S/N	Loc.	Model	S/N
5C02 $3/32$ 6C02 $3/333$ 7C02 $4_0272$ 8C02 $3/33$ 9C02 $3/330$ 10C02 $4_0275$ 11C02 $3/334$ 12C02 $4_02$ 13B02 $1/(437)$ Aluminum LSC panel severance: $\sqrt{20}$ No )Post-test visually inspected observations: $M_b$ (base a ccels. or bo(ts.Group: I - Test No.: 7Date: $5 - 9 - 20/3$ Test Article Desc.: $IM7/TC350$ Solid Composite Pansee appendix B for ply layup, 3'x6'x0.2"Test Article Configuration: hangingTest Article Drawing #: $97M00200$ -GRP I-TEST 7Material: $IM7/TC350$ PID# $0320A00$ Test Article Drawing #: $97M00200$ -GRP I-TEST 7Material:Aluminum S/N: PathfinderTest Article Drawing #: $97M00203$ -MODMaterial:Aluminum S/N: PathfinderTest Article Drawing #: $97M00204$ -MOD-222Material:Aluminum S/N: PathfinderShock Source:LSC L/N: noneLSC Core Load: 22 GR/FTExplosive Material:CH-6Sheath:Aluminum Actual Length Used: $4'$ Loc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/NLoc.ModelS/N </td <td>1</td> <td>C02</td> <td>31334</td> <td>2</td> <td>C02</td> <td>31340</td> <td>3</td> <td>C02</td> <td>31338</td> <td>4</td> <td>C02</td> <td>31331</td>	1	C02	31334	2	C02	31340	3	C02	31338	4	C02	31331
9C023/3210C02 $\sqrt{9295}$ 11C02 $3/334$ 12C02 $462$ 13B02 $1/(439)$ Aluminum LSC panel severance: (Tes) No )Post-test visually inspected observations: $N_b$ (pare a cccls. or bo( $tx$ .Group: I - Test No.: 7Date: $5-9-20/7$ Test Article Desc.: $IM7/TC350$ Solid Composite Pansee appendix B for ply layup, 3'x6'x0.2"Test Article Configuration: hangingTest Article Drawing #: $97M00200$ -GRP I-TEST 7Material: $IM7/TC350$ PID# $0320A000$ Test Article Drawing #: $97M00202$ Material: Aluminum S/N: PathfinderTest Article Drawing #: $97M00203$ -MODMaterial: Aluminum S/N: PathfinderTest Article Drawing #: $97M00203$ -MODMaterial: Aluminum S/N: PathfinderTest Article Drawing #: $97M00204$ -MOD-2-22Material: Aluminum S/N: PathfinderShock Source: LSC L/N: noneLSC Core Load: $22$ GR/FTExplosive Material: CH-6Sheath: Aluminum Actual Length Used: $U'$ Accelerometer MFG: PCB Model: $350XXX$ Loc. ModelLoc. ModelLoc. ModelS/NLoc. Model <tr< td=""><td>5</td><td>C02</td><td>31928</td><td>6</td><td>C02</td><td>31333</td><td>7</td><td>C02</td><td>40292</td><td>8</td><td>C02</td><td>31351</td></tr<>	5	C02	31928	6	C02	31333	7	C02	40292	8	C02	31351
13B02 $lt 439$ Aluminum LSC panel severance: (Yes) No )Post-test visually inspected observations: $N_b$ loase a ccels. or $b_0/t_3$ .Group: I - Test No.: 7 Date: $5 - 9 - 20/3$ Test Article Desc.: IM7/TC350 Solid Composite Panesee appendix B for ply layup, 3'x6'x0.2"Test Article Configuration: hangingTest Article Drawing #: 97M00200-GRP I-TEST 7 Material: IM7/TC350 PID# $0320A00$ Test Article Drawing #: 97M00200-GRP I-TEST 7 Material: IM7/TC350 PID# $0320A00$ Test Article Drawing #: 97M00202 Material: Aluminum S/N: PathfinderTest Article Drawing #: 97M00203-MOD Material: Aluminum S/N: PathfinderTest Article Drawing #: 97M00204-MOD-2-22 Material: Aluminum S/N: PathfinderTest Article Drawing #: 97M00204-MOD-2-22 Material: Aluminum S/N: PathfinderShock Source: LSC L/N: noneLSC Core Load: 22 GR/FT Explosive Material: CH-6Sheath: Aluminum Actual Length Used: $U'$ Accelerometer MFG: PCB Model: 350XXXLoc. Model S/N Loc. Model S/N Loc. Model S/N Loc. Model S/N1C02 3/324 29C02 3/330 109C02	9	C02	31330	10	C02	40295	11	C02	31334	12	C02	40274
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Accelerometer MFG: PCB Model: $350XXX$ Loc.       Model       S/N       Loc.       Model       S/N       Loc.       Model       S/N         1       C02 $3/324$ 2       D02 $43024$ 3       D02 $43028$ 4       C02 $313$ 5       C02 $3/328$ 6       D02 $43024$ 7       D02 $43/79$ 8       C02 $3132$ 9       C02 $3/320$ 10       D02 $43/80$ 11       D02 $43/81$ 12       C02 $462$ 13       B02 $1/439$ 402         Aluminum LSC panel severance: (Yes)/No <td< th=""><th>Grou see a</th><th>p: <u>I</u> - Test</th><th>t No.: 7 D</th><th>)ate: <u>5</u> ayup, 3</th><th>-9-201 'x6'x0.2</th><th>7 Test Ar</th><th>ticle D</th><th>esc.: <u>IM7</u></th><th>//TC350 §</th><th>Solid C</th><th>Composit</th><th>e Panel,</th></td<>	Grou see a	p: <u>I</u> - Test	t No.: 7 D	)ate: <u>5</u> ayup, 3	-9-201 'x6'x0.2	7 Test Ar	ticle D	esc.: <u>IM7</u>	//TC350 §	Solid C	Composit	e Panel,
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1       C02       31328       2       D02       43029       3       D02       43028       4       C02       313         5       C02       31328       6       D02       43029       7       D02       43179       8       C02       313         9       C02       31330       10       D02       43180       11       D02       43181       12       C02       462         13       B02       11439             402         Aluminum LSC panel severance: (Yes)/No)	Grou see a Test Test Test Test Shoc Shea Acce	p: <u>1</u> - Tes ppendix <u>1</u> Article D Article D Article D Article D Article D k Source: th: <u>Alumi</u> lerometer	t No.: 7 D 3 for ply la onfiguration rawing #: rawing #: rawing #: LSC L/N num Act MFG: PC	Date: <u>9</u> ayup, 3 on: har 97M00 97M00 97M00 97M00 97M00 : <u>non</u> ual Le 2B Mc	7-9-201 <sup>1</sup> 'x6'x0.2 <u>1200-GR</u> <u>12003-MO</u> <u>1204-MO</u> <u>e</u> LS ngth User del: <u>350</u>	P I-TEST aterial: <u>A</u> <u>D</u> Mate <u>D-2-22</u> C Core L <u>1</u> : <u>4'</u> XXX	ticle D <u>7</u> Ma luminu rial: <u>A</u> Materi .oad: <u>2</u>	esc.: <u>IM7</u> terial: <u>IM</u> m S/N: <u>J</u> luminum al: <u>Alum</u> 2 GR/FT	17/TC350 S 17/TC350 Pathfinde S/N: Pat inum S/T Explosi	Solid C PID# I thfinde N: Path ive Ma	Composite 0320 Infinder terial: CI	<u>e Panel.</u> <u>A 00</u> 7 <u>H-6</u>
9         C02         31348         0         D02         43027         7         D02         43174         8         C02         312         312         312         312         312         312         312         312         312         312         312         312         312         312         402         43181         12         C02         462         462         431         402         43181         12         C02         462         462         431         402         43181         12         C02         462         462         431         402         43181         12         C02         462         462         402 </td <td>Grou see a Test Test Test Test Shoc Shea Accee Loc.</td> <td>p: I - Tes ppendix I Article D Article D Article D Article D Article D k Source: th: Alumi lerometer Model</td> <td>t No.: 7 D 3 for ply la onfiguration rawing #: rawing #: rawing #: LSC L/N num Act MFG: PC 3/2011</td> <td>Date: <u>9</u> ayup, 3 on: har <u>97M00</u> 97M00 97M00 97M00 : <u>nen</u> ual Le <u>2B Mc</u> Loc.</td> <td>5-9-201 <sup>1</sup>'x6'x0.2 <u>19</u>ing <u>0</u>200-GR <u>0</u>2003-MO <u>0</u>204-MO <u>e</u>LS ngth User del: <u>350</u> Model <u>0</u>025</td> <td>P I-TEST aterial: <u>A</u> D Mate D-2-22 C Core L d: <u>4'</u> XXX S/N</td> <td>ticle D 7 Ma luminu rial: <u>A</u> Materi .oad: <u>2</u> Loc.</td> <td>esc.: <u>IM7</u> terial: <u>IM</u> m S/N: j luminum al: <u>Alum</u> 2 GR/FT Model</td> <td>2/TC350 S (7/TC350 S Pathřínde S/N: <u>Pat</u> inum S/T Explosi</td> <td>Solid C PID# I thfinde N: Path ive Ma</td> <td>Compositi 0320 Infinder terial: CI Model</td> <td><u>e Panel.</u> <u>A 00</u>7 <u>H-6</u></td>	Grou see a Test Test Test Test Shoc Shea Accee Loc.	p: I - Tes ppendix I Article D Article D Article D Article D Article D k Source: th: Alumi lerometer Model	t No.: 7 D 3 for ply la onfiguration rawing #: rawing #: rawing #: LSC L/N num Act MFG: PC 3/2011	Date: <u>9</u> ayup, 3 on: har <u>97M00</u> 97M00 97M00 97M00 : <u>nen</u> ual Le <u>2B Mc</u> Loc.	5-9-201 <sup>1</sup> 'x6'x0.2 <u>19</u> ing <u>0</u> 200-GR <u>0</u> 2003-MO <u>0</u> 204-MO <u>e</u> LS ngth User del: <u>350</u> Model <u>0</u> 025	P I-TEST aterial: <u>A</u> D Mate D-2-22 C Core L d: <u>4'</u> XXX S/N	ticle D 7 Ma luminu rial: <u>A</u> Materi .oad: <u>2</u> Loc.	esc.: <u>IM7</u> terial: <u>IM</u> m S/N: j luminum al: <u>Alum</u> 2 GR/FT Model	2/TC350 S (7/TC350 S Pathřínde S/N: <u>Pat</u> inum S/T Explosi	Solid C PID# I thfinde N: Path ive Ma	Compositi 0320 Infinder terial: CI Model	<u>e Panel.</u> <u>A 00</u> 7 <u>H-6</u>
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Post-test visually inspected observations: No loose bolts or accels, except Al went to 25 in-16 and the insert started to spin.	Grou see a Test Test Test Test Shoc Shoca Shea Acce Loc. 1 5 9 13	p: <u>I</u> - Tes ppendix I Article C Article D Article D Article D k Source: th: <u>Alumi</u> lerometer <u>Model</u> <u>C02</u> <u>C02</u> <u>C02</u> <u>B02</u>	t No.: 7 D 3 for ply la onfiguration rawing #: rawing #: rawing #: LSC L/N LSC L/N MFG: PC S/N 3/324 3/328 3/330 1/439	Date:	7-9-2013 3'x6'x0.2 19200-GR 9200-GR 9202-M0 9203-M0 9204-M0 e LS ngth Usea LS ngth Usea Model 902 902 902 902 902	7 Test Ar P I-TEST aterial: <u>A</u> D-2-22 C Core L d: <u>4</u> XXX S/N <u>43024</u> <u>43029</u>	ticle D <u>7</u> Ma luminu rial: <u>A</u> Materi .oad: <u>2</u> <u>Loc.</u> <u>3</u> 7 11	terial: <u>IM7</u> m S/N; J luminum al: <u>Alum</u> 2 GR/FT <u>Model</u> D02 D02 D02	2/TC350 S Pathfinde S/N: Pat inum S/? Explosi S/N 43028 43179 43181	Solid C PID# PID# PID# PID# PID# PID# PID# PID#	Compositi 0320 finder terial: CI Model C02 C02 C02	e Panel, A 007 H-6 S/N 31331 31351 Ho274



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Shock Sc Sheath: <u>/</u> Accelero Loc. M <u>1</u> I <u>5</u> I <u>9</u> I <u>13</u> H Aluminu Post-test Group: <u>I</u> <u>sce apper</u> Test Arti Test Arti	Aluminu ometer M Model D02 4 D02 4 B02 1 um LSC p t visually	SC L/N im A MFG: <u>PC</u> S/N <b>43026</b> <b>43027</b> <b>43027</b> <b>43180</b> 11439 panel se y inspect	: none ctual I CB Mc Loc. 2 6 10 everand ted obs	Lo cength Us odel: <u>350</u> Model C02 C02 C02 C02 ce: (Yes servations	Sc Core I sed:	Loc. 3 7 11 pore bo	Model C02 C02 C02	S/N 31 338 40292 31 336	Loc. 4 8 12	Model D02 D02 D02	S/N 4302 4317 4318
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Aluminu	um LSC p	panel se	verand	ce: (Yes)	/ No )		1.000				
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	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 12-00783	Version: 1.0								
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Title: Emnir	ical Model Development for Predicting Shock Re	esponse on	Page #: 645 of 793								

#### Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading

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				TEST	DATA	SHEE	T, cont	t.			
Grour	: I - Test	No.: 10	Date:	5-29-20	3 Test Ar	ticle D	esc.: IM7	/TC350 9	Solid C	Composit	e Panel,
see ap	pendix H	B for ply l	ayup,	3'x6'x0.2	···						
Test A	Article Co	onfigurati	on: han	nging	DITECT	10 1	(	MATTON	60 DI	D# 020	11010
Test A	Article Di	rawing #:	97M0	0200-GR	aterial: A	luminu	m $S/N$	Pathfinde	<u>50</u> PI r	D# 024	(4A B10
Test A	Article D	rawing #:	97M0	0203-MO	D Mate	rial: A	uminum	S/N: Pat	hfinde	r	
Test /	Article Di	rawing #:	<u>97M0</u>	0204-MO	D-2-10	Materi	al: Alum	inum S/1	N: Path	nfinder	
Shock	Source:	LSC L/N	: none	LS enoth Us	C Core L	Load: 1	0 GR/FT	Explosi	ive Ma	terial: <u>RI</u>	DX
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1	D02	43026	2	C02	31340	3	C02	31338	4	D02	43028
2	D02	43029	0	C02	31333	/	C02	40292	12	D02	43179
13	B02	114 79	10	002	40273	11	0.02	21336	14	1002	42101
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# NESC-DEV-13-015 Composite Materials Shock Test

### Test #6 Accelerometer Data Panel 0326A006

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# NESC-DEV-13-015 Composite Materials Shock Test

## Test #7 Accelerometer Data Panel 0326A007

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## NESC-DEV-13-015 Composite Materials Shock Test

## Test #8 Accelerometer Data Panel 0326A008

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## NESC-DEV-13-015 Composite Materials Shock Test

## Test #9 Accelerometer Data Panel 0326A009

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## NESC-DEV-13-015 Composite Materials Shock Test

## Test #10 Accelerometer Data Panel 0326A0010

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NESC-DEV-13-015							
Equipment List							
Description	Manufacturer	Mocel/Version	ID/Serial Number	Location	Cal Due Date		
	2	2	2				
Shock Analysis Tool	CT 40	1.2.5		2	Verified 5/21/2009		
TEAM256	Nicolet	7.20			Verified 7/26/2012		
Torque Wrench	Proto	6066C	M658396		10/8/2013		
Torque Wrench	Precision Instruments	44620	M658783		10/4/2013		
Power Supply	Enclevco	2793	M652262		1/10/2014		
Data Acquisition System	Nicolet	BE256LE	2011288	Channels 2-8, 10-15	8/6/2014		
Channel 2	Nicolet	614CB	001 2	A1	8/6/2014		
Channel 3	Nicolet	614CB	001-3	A2	8/6/2014		
Channel 4	Nicolet	614CB	001-4	A3	8/6/2014		
Channel 5	Nicolet	614CB	002-1	A4	8/6/2014		
Channel 6	Nicolet	614CB	002 2	A5	8/6/2014		
Channel 7	Nicolet	614CB	002-3	A6	8/6/2014		
Channel 8	Nicolet	614CB	002 4	A7	8/6/2014		
Channel 10	Nicolet	614CB	00.3-2	A8	8/6/2014		
Channel 11	Nicolet	614CB	003-3	A9	8/6/2014		
Channel 12	Nicolet	614CB	003-4	A10	8/6/2014		
Channel 13	Nicolet	614CB	004 1	A11	8/6/2014		
Channel 14	Nicolet	614CB	004-2	A12	8/6/2014		
Channel 15	Nicolet	614CB	004-3	A13	8/6/2014		
Accelerometer	PCB	350C02	31334	Set 1 A1 (tests 6, 7 & 9)	4/23/2014		
Accelerometer	PCB	350D02	43026	Set 1 A2 (tests 7 & 9)	4/23/2014		
Accelerometer	PCB	350D02	43028	Set 1 A3 [tests 7 & 9]	4/23/2014		
Accelerometer	PCB	350C02	31331	Set 1 A4 (tests 6, 7 & 9)	1/22/2015		
Accelerometer	PCB	350C02	31328	Set 1 A5 (tests 6, 7 & 9)	4/24/2014		
Accelerometer	PCB	350D02	43029	Set 1 A6 (tests 7 & 9)	4/23/2014		
Accelerometer	PCB	350D02	43179	Set 1 A7 (tests 7 & 9)	4/22/2014		
Accelerometer	PCB	350C02	31351	Set 1 A8 (tests 6, 7 & 9)	6/5/2015		
Accelerometer	PCB	350002	31330	Set 1 A9 (tests 6, 7 & 9)	4/24/2014		
Accelerometer	PCB	350D02	43180	Set 1 A10 (tests 7 & 9)	4/23/2014		
Accelerometer	PCB	350D02	43181	Set 1 A11 (tests 7 & 9)	4/23/2014		
Accelerometer	PCB	350C02	40274	Set 1 A12 (tests 6, 7 & 9)	6/5/2015		
Accelerometer	PCB	350D02	43026	Set 2 A1 (tests 8 & 10)	1/22/2015		
Accelerometer	PCB	350C02	31340	Set 2 A2 (tests 8 & 10)	4/23/2014		
Accelerometer	PCB	350C02	31338	Set 2 A3 (tests 6, 8 & 10)	4/24/2014		
Accelerometer	PCB	350D02	43028	Set 2 A4 (tests 8 & 10)	1/22/2015		
Accelerometer	PCB	350D02	43029	Set 2 A5 (tests 8 & 10)	4/23/2014		
Accelerometer	PCB	350C02	31333	Set 2 A6 (tests 8 & 10)	4/24/2014		
Accelerometer	PCB	350C02	40292	Set 2 A7 (tests 6, 8 & 10)	4/24/2014		
Accelerometer	PCB	350D02	43179	Set 2 A8 (tests 8 & 10)	1/22/2015		
Accelerometer	PCB	350D02	43180	Set 2 A9 (tests 8 & 10)	1/22/2015		
Accelerometer	PCB	350C02	40295	Set 2 A10 (tests 6, 8 & 10)	4/24/2014		
Accelerometer	PCB	350C02	31336	Set 2 A11 (tests 6, 8 & 10)	4/24/2014		
Accelerometer	PCB	350D02	43181	Set 2 A12 (tests 8 & 10)	1/22/2015		
Accelerometer	PCB	350B02	11439	Set 1 and 2 A13 (all tests)	4/29/2014		
Accelerometer	PCB	350C02	31340	A2 test 6	4/23/2014		
Accelerometer	PCB	350C02	31333	A6 test 6	4/24/2014		

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### **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

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TEAM256 SETTINGS Date: 05-08-2013 Time: 14:25:17 C:\TEAMPRO Storage Path: Filename: Data File Number: 001 C:\TEAM256 Settings Path: Settings File: NES106.SET Export Path: D:\ATEST\NESC\_3\NEST1-06\RAWDAT~1 Export Format: FAMOS Average Blocks: No Between Cursors: No BE1 Frequency A : Pre Trigger : 1.0000 MHz(Internal) 48000 Samples (48.00 ms) Segment A 1000576 Samples (1.001 s) Number of Blocks : Digital Event Channels : Analog Channels : 0 Filter 33.00 k 33.00 k Min Trigger Off Nr. Name Max Units Coup. Amp. 55.56 kg's pk 28.85 kg's pk -55.56 XXX 1 GND DC DC 2 NES\_2 Basic -28.85 -31.58 -30.00 -27.78 -28.04 34 NES\_3 31.56 30.00 kg's pk 27.78 kg's pk 28.04 kg's pk 28.57 kg's pk 31.58 kg's pk 33.00 k Basic 33.00 k 33.00 k 33.00 k DC DC NES\_4 + Basic NES 5 567 Basic NES\_6 NES\_7 DC Basic 33.00 k 33.00 k 33.00 k -28.57 DC Basic -28.30 -55.56 28.30 kg's pk 55.56 kg's pk DC 89 NES\_8 Basic GND Off XXX 9 kg's pk kg's pk ++ DC DC DC 33.00 k 33.00 k 33.00 k 10 NES\_10 -28.04 28.04 Off NES\_10 -28.04 NES\_11 -27.03 NES\_12 -28.30 NES\_13 -27.78 NES\_14 -27.27 NES\_15 -8.929 ROC\_16 -55.56 ROC\_17 -55.56 11 27.03 kg's pk Off Off 28.30 kg's pk 27.78 kg's pk 27.27 kg's pk 12 + 13 DC 33.00 k Off DC DC DC DC DC DC DC DC 33.00 k k Off 14 8.929 55.56 55.56 33.00 + + + Off 15 kg's pk k kg's pk kg's pk Off 16 33.00 k 33.00 k 33.00 k 33.00 k 33.00 k Off 17 ROC\_18 -55.56 ROC\_19 -55.56 ROC\_20 -55.56 Off Off 55.56 kg's pk 18 55.56 kg's pk 55.56 kg's pk 19 20 ROC\_20 -55.56 55.56 kg's pk DC Engineering Units Scaling XXX\_1 0 + 9.2593 k \* Voltage (g's pk) NES\_2 0 + 9.6154 k \* Voltage (g's pk) NES\_3 0 + 10.526 k \* Voltage (g's pk) NES\_4 0 + 10.000 k \* Voltage (g's pk) NES\_5 0 + 9.2593 k \* Voltage (g's pk) NES\_6 0 + 9.3458 k \* Voltage (g's pk) NES\_7 0 + 9.5238 k \* Voltage (g's pk) NES\_8 0 + 9.4340 k \* Voltage (g's pk) NES\_10 0 + 9.3458 k \* Voltage (g's pk) NES\_11 0 + 9.0909 k \* Voltage (g's pk) NES\_11 0 + 9.4340 k \* Voltage (g's pk) NES\_13 0 + 9.2593 k \* Voltage (g's pk) NES\_14 0 + 9.0909 k \* Voltage (g's pk) NES\_15 0 + 8.9286 k \* Voltage (g's pk) NES\_15 0 + 9.2593 k \* Voltage (g's pk) NES\_16 0 + 9.2593 k \* Voltage (g's pk) NES\_17 0 + 9.2593 k \* Voltage (g's pk) NES\_17 0 + 9.2593 k \* Voltage (g's pk) NES\_17 0 + 9.2593 k \* Voltage (g's pk) NES\_17 0 + 9.2593 k \* Voltage (g's pk) NES\_17 0 + 9.2593 k \* Voltage (g's pk) NES\_17 0 + 9.2593 k \* Voltage (g's pk) NES\_17 0 + 9.2593 k \* Voltage (g's pk) 20 off ROC\_17 0 + 9.2593 \* \* k Voltage (g's pk) ROC\_18 0 + 9.2593 k 9.2593 k Voltage (g's pk) Voltage (g's pk) 0 + 0 + ROC 19 ROC\_20 9.2593 k \* Voltage (g's pk) Trigger Settings : Off

Auto Trigger:

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1.0

### (g's pk) (g's pk) Voltage (g's Voltage pk) Voltage Voltage (g's (g's pk) pk) Voltage (g's pk) Voltage Voltage Voltage (g's pk) (g's (g's pk) pk) Voltage (g's pk) Voltage Voltage (g's pk) \* \* \* \* (g's pk) Voltage (g's pk) 0 + 9.2593 k0 + 9.2593 kVoltage (g's pk) Voltage (g's pk) 9.2593 k \* Voltage (g's pk)

Voltage

Voltage

(g's pk)

Trigger Settings : Off Auto Trigger:

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ROC\_18

ROC 19

ROC\_20



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## **Empirical Model Development for Predicting Shock Response on Composite Materials Subjected to Pyroshock Loading**

TEAM256 SETTINGS Date: 05-16-2013 Time: 13:43:37 Storage Path: C:\TEAMPRO Filename: File Number: Data 001 C:\TEAM256 Settings Path: Settings File: NES108.SET Export Path: D:\ATEST\NESC\_3\NEST1-08\RAWDAT~1 Export Format: FAMOS Average Blocks: No Between Cursors: No BE1 1.0000 MHz(Internal) Frequency A : Pre Trigger : 48000 Samples (48.00 ms) Segment A : Number of Blocks : Digital Event Channels : 1000576 Samples (1.001 s) 0 Analog Channels : Filter 33.00 k Max Units 55.56 kg's pk 30.93 kg's pk Nr. Name Min Coup. Amp. Trigger -55.56 GND Off 1 XXX 1 +++ DC DC DC DC DC DC DC DC 2 NES\_2 Basic 345 -31.58 -30.00 -31.25 31.58 kg's pk 30.00 kg's pk 31.25 kg's pk NES\_3 + Basic NES\_4 NES\_5 Basic + Basic NES\_6 NES\_7 NES\_8 67 -30.30 30.30 kg's pk + Basic -28.57 -28.30 -55.56 28.57 28.30 kg's pk kg's pk kg's pk Basic 8 Basic XXX\_9 55.56 GND XXX\_9 -55.56 NES\_10 -30.61 NES\_11 -31.58 NES\_12 -28.30 NES\_13 -27.78 NES\_14 -30.61 NES\_15 -8.929 ROC\_16 -55.56 ROC\_17 -55.56 ROC\_18 -55.56 ROC\_19 -55.56 ROC\_20 -55.56 Off DC DC DC Off Off 10 30.61 kg's pk 31.58 28.30 27.78 30.61 8.929 55.56 11 kg's pk kg's pk + Off 12 13 kg's pk DC DC DC DC DC DC DC Off ++ kg's pk kg's pk kg's pk Off 14 Off 15 16 Off 55.56 55.56 55.56 kg's pk kg's pk kg's pk 17 +++ Off 18 Off Off 19 kg's pk 55.56 DC Off 20 Voltage (g's pk) Voltage (g's pk) Voltage (g's pk) (g's pk) (g's pk) Voltage Voltage Voltage (g's pk) Voltage (g's pk) (g's pk) Voltage Voltage (g's pk) Voltage Voltage (g's pk) (g's pk) (g's pk) Voltage Voltage (g's pk) Voltage Voltage (g's pk) (g's pk) Voltage (g's pk) Voltage (g's pk) Voltage (g's pk) Voltage (g's pk) 0 + 0 + 9.2593 k \* ROC 19 ROC\_20 9.2593 k \* Voltage (g's pk) Trigger Settings : Auto Trigger: Off

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### TEAM256 SETTINGS Date: 05-17-2013 Time: 08:30:27 Storage Path: C:\TEAMPRO Filename: Data 001 File Number: C:\TEAM256 Settings Path: Settings File: NES109.SET Export Path: D:\ATEST\NESC\_3\NEST1-09\RAWDAT~1 Export Format: FAMOS Average Blocks: No Between Cursors: No BE1 1.0000 MHz(Internal) Frequency A : 48000 Samples (48.00 ms) 1000576 Samples (1.001 s) Pre Trigger : Segment A : Number of Blocks : Digital Event Channels : ō Analog Channels : Nr. Name 1 XXX\_1 2 NES\_2 Max Units 6.000 kg's pk 28.85 kg's pk Filter 33.00 k Coup. Amp. GND + Min Trigger -6.000 -28.85 Off Basic +++ DC DC DC DC 3 NES\_3 -30.93 30.93 kg's pk + Basic -31.25 31.25 kg's pk 27.78 kg's pk 28.04 kg's pk 45 NES\_4 NES\_5 + Basic Basic 678 NES\_6 -28.04 DC Basic NES\_7 -30.30 30.30 kg's pk DC DC Basic NES\_7 - 30.30 NES\_8 - 30.61 XXX\_9 - 6.000 NES\_10 - 28.04 NES\_11 - 27.03 NES\_12 - 31.58 NES\_13 - 30.61 30.61 6.000 kg's pk kg's pk +++ Basic 9 GND Off 28.04 27.03 31.58 10 kg's pk Off kg's pk kg's pk kg's pk 11 12 +++ Off off 31.58 30.61 27.27 8.929 55.56 13 Off NES\_13 -30.61 NES\_14 -27.27 NES\_15 -8.929 ROC\_16 -55.56 ROC\_17 -55.56 ROC\_18 -55.56 ROC\_19 -55.56 ROC\_20 -55.56 14 kg's pk Off kg's pk kg's pk Off 15 16 Off DC DC DC DC 33.00 k 33.00 k 33.00 k 55.56 kg's pk Off 55.56 kg's pk 55.56 kg's pk 55.56 kg's pk 18 Off Off 19 20 ROC\_19 -55.56 55.56 kg's pk DC Engineering Units Scaling XXX\_1 0 + 1.0000 k \* Voltage (g's pk) NES\_2 0 + 9.6154 k \* Voltage (g's pk) NES\_3 0 + 10.309 k \* Voltage (g's pk) NES\_4 0 + 10.417 k \* Voltage (g's pk) NES\_5 0 + 9.2593 k \* Voltage (g's pk) NES\_6 0 + 9.3458 k \* Voltage (g's pk) NES\_7 0 + 10.101 k \* Voltage (g's pk) NES\_8 0 + 10.204 k \* Voltage (g's pk) NES\_10 0 + 9.3458 k \* Voltage (g's pk) NES\_10 0 + 9.3458 k \* Voltage (g's pk) NES\_10 0 + 9.3458 k \* Voltage (g's pk) NES\_10 0 + 9.3458 k \* Voltage (g's pk) NES\_11 0 + 9.0090 k \* Voltage (g's pk) NES\_12 0 + 10.204 k \* Voltage (g's pk) NES\_13 0 + 10.204 k \* Voltage (g's pk) NES\_14 0 + 9.0909 k \* Voltage (g's pk) NES\_15 0 + 8.9286 k \* Voltage (g's pk) ROC\_16 0 + 9.2593 k \* Voltage (g's pk) ROC\_17 0 + 9.2593 k \* Voltage (g's pk) ROC\_18 0 + 9.2593 k \* Voltage (g's pk) 33.00 k 20 Off 9.2593 k \* Voltage (g's pk) 9.2593 k \* Voltage (g's pk) 9.2593 k \* Voltage (g's pk) 0 + 0 + 0 + ROC\_18 ROC\_19 9.2593 k \* Voltage (g's pk) ROC\_20 Trigger Settings : Auto Trigger: Off



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Version:

1.0

### TEAM256 SETTINGS Date: 05-29-2013 Time: 08:21:10 C:\TEAMPRO Storage Path: Filename: Data File Number: 001 C:\TEAM256 NES110.SET Settings Path: Settings File: Export Path: D:\ATEST\NESC\_3\NEST1-10\RAWDAT~1 Export Format: Average Blocks: FAMOS No Between Cursors: No BE1 1.0000 MHz(Internal) 48000 Samples (48.00 ms) 1000576 Samples (1.001 s) Frequency A : Pre Trigger : Segment A : Number of Blocks : Digital Event Channels : Analog Channels : Nr. Name Min Max 0 els: Min Max Units -6.000 6.000 kg's pk -30.93 30.93 kg's pk -31.58 31.58 kg's pk -30.00 30.00 kg's pk -31.25 31.25 kg's pk -30.30 30.30 kg's pk -28.57 28.57 kg's pk -28.57 28.57 kg's pk Filter 33.00 k Coup. Amp. Trigger GND DC DC +++++ 1 XXX\_1 Off Basic NES\_2 NES\_3 2 Basic 3 DC DC DC 4 NES\_4 Basic NES\_5 NES\_6 Basic 5 6 Basic 33.00 k NES\_0 NES\_7 NES\_8 XXX\_9 DC DC GND Basic 28.30 kg's pk 28.30 kg's pk 6.000 kg's pk 30.61 kg's pk 31.58 kg's pk NES\_8 -28.30 XXX\_9 -6.000 NES\_10 -30.61 NES\_11 -31.58 NES\_12 -28.30 NES\_13 -27.78 8 Basic Off 9 DC DC DC DC Off 10 31.58 kg's pk 28.30 kg's pk 27.78 kg's pk 30.61 kg's pk Off 11 Off 12 Off 13 NES\_13 -27.78 NES\_14 -30.61 NES\_15 -8.929 ROC\_16 -55.56 ROC\_17 -55.56 ROC\_18 -55.56 ROC\_19 -55.56 ROC\_20 -55.56 33.00 k 33.00 k 33.00 k 14 DC Off kg's pk kg's pk kg's pk Off Off 15 8.929 DC DC DC DC DC DC DC 55.56 kg's pk 16 33.00 k 33.00 k 33.00 k 33.00 k 33.00 k 17 Off 18 Off Off 19 19 ROC\_19 -55.56 55.56 kg's pk DC 20 ROC\_20 -55.56 55.56 kg's pk DC Engineering Units Scaling XXX\_1 0 + 1.0000 k \* Voltage (g's pk) NES\_2 0 + 10.309 k \* Voltage (g's pk) NES\_3 0 + 10.526 k \* Voltage (g's pk) NES\_5 0 + 10.417 k \* Voltage (g's pk) NES\_6 0 + 10.417 k \* Voltage (g's pk) NES\_6 0 + 10.417 k \* Voltage (g's pk) NES\_7 0 + 9.5238 k \* Voltage (g's pk) NES\_10 0 + 1.0000 k \* Voltage (g's pk) NES\_10 0 + 1.0000 k \* Voltage (g's pk) NES\_10 0 + 1.0000 k \* Voltage (g's pk) NES\_10 0 + 1.0000 k \* Voltage (g's pk) NES\_10 0 + 1.0000 k \* Voltage (g's pk) NES\_11 0 + 10.526 k \* Voltage (g's pk) NES\_13 0 + 9.2593 k \* Voltage (g's pk) NES\_14 0 + 10.204 k \* Voltage (g's pk) NES\_15 0 + 8.9286 k \* Voltage (g's pk) NES\_15 0 + 9.2593 k \* Voltage (g's pk) ROC\_16 0 + 9.2593 k \* Voltage (g's pk) ROC\_17 0 + 9.2593 k \* Voltage (g's pk) ROC\_18 0 + 9.2593 k \* Voltage (g's pk) ROC\_20 0 + 9.2593 k \* Voltage (g's pk) ROC\_20 0 + 9.2593 k \* Voltage (g's pk) Trigger Settings : Off 20 Trigger Settings : Auto Trigger: Off

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The NASA Engineering and Safety Center (NESC) received a request to develop an analysis model based on both frequency response and wave propagation analyses for predicting shock response spectrum (SRS) on composite materials subjected to pyroshock loading. The model would account for near-field environment (~9 inches from the source) dominated by direct wave propagation, mid-field environment (~2 feet from the source) characterized by wave propagation and structural resonances, and far-field environment dominated by lower frequency bending waves in the structure. This document contains appendices to the Volume I report.							
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