ENVIRONMENTAL TEST REPORT
SMARTSCAN AERO MINI INTEROGATOR

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A	7 July 2016	New document

1 BACKGROUND

The purpose of the environmental tests was to determine the ability of the SmartScan Aero Mini to withstand the environmental conditions described herein, without any failure, malfunction, or out-of-tolerance issues.

2 APPLICABLE DOCUMENTS

Documents applicable to these tests include:

- MIL-STD-810F : Environmental Test Methods and Engineering Guidelines
- MIL-STD-810G : Environmental engineering considerations and laboratory tests

3 DESCRIPTION OF UNIT

The Unit is described as:

SmartScan Aero Mini PN: 7082-2002 SN: 139956
SmartScan Aero Mini PN: 7082-2002 SN: 139727

4 SCOPE

The two Units were subject to the following scope:

08/04/2016	MIL-STD-810G Vibration Test (SN: 139956)
10/05/2016	MIL STD 810G Shock testing (SN: 139727)
20/05/2016	Thermal cycling (SN: 139727)

5 EQUIPMENT

The equipment used for the tests listed in sections 6-0:

Equipment	Manufacturer	Model S/N:	Range
Vibration Shaker	Bruel & Kjaer LDS Test and Measurement	V650	0-100g 5-4000Hz
Control Accelerometer	Bruel & Kjaer	61740	1-20kHz
Reference Accelerometer	Bruel & Kjaer	62567	1-10kHz
Conditioning Amplifier	Bruel & Kjaer LDS Test and Measurement	PA1000L	
Data Acquisition System	Bruel & Kjaer LDS Test and Measurement		
Athermal FBGs 1535nm, 1550nm, 1565nm	Smart Fibres	41202-1 41125-20 41125-33	.Reflectivity 97% FWHM 0.23 nm
Digital Thermometer and K type thermocouples	RS	140205871	-50 to 1100 ^{o}C
Dry well	Fluke	B2A438	35 to 250 ^{o}C
Dry well FBGs	Smart Fibres		Reflectivity 50% FWHM 0.8nm
Thermal chamber	ESPEC	SU 241	-40 to 150 °C

6 VIBRATION

6.1 PROCEDURE

The unit under test (UUT) was fastened to the test fixture by its normal mounting means; an M6 screw through each of four designated holes at each corner. The test plate was in turn secured to the Vibration table. The vibration input was measured by a reference accelerometer mounted on the fixture close as possible to the test item.

The unit was connected to three athermal FBG test articles connected in series on one of the fibre channels. These were not subject to vibration. Athermal FGBs have mechanical compensation to reduce their temperature dependency to close to 0 pm/ ^{o}C. Wavelength data was recorded using SmartSoft.

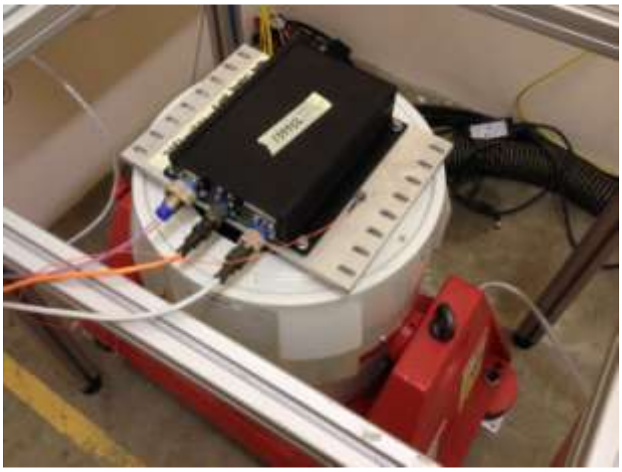

Figure 1: Aero mini mounted on vibration rig

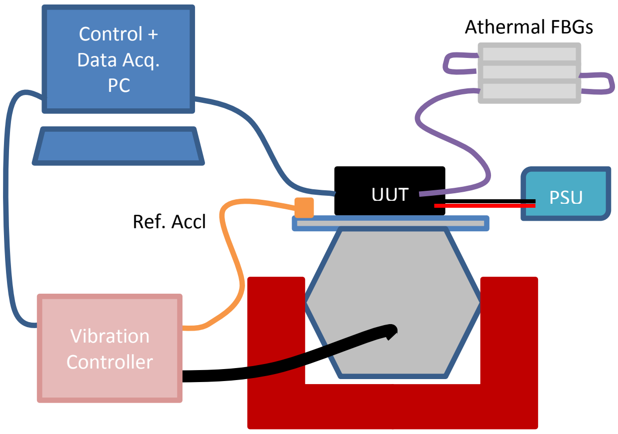

Figure 2: Connection diagram

6.2 VIBRATION PROFILE

Random Vibration was applied, in 1 axis, in accordance with MIL-STD-810G, Method 514.6, Annex D, Category 12, over the appropriate frequency range of 15-2000 Hz for a period of 30 minutes. The applied profile is shown in Figure 3, where W_0 is 0.1 g^2/Hz equating to about 11 g.

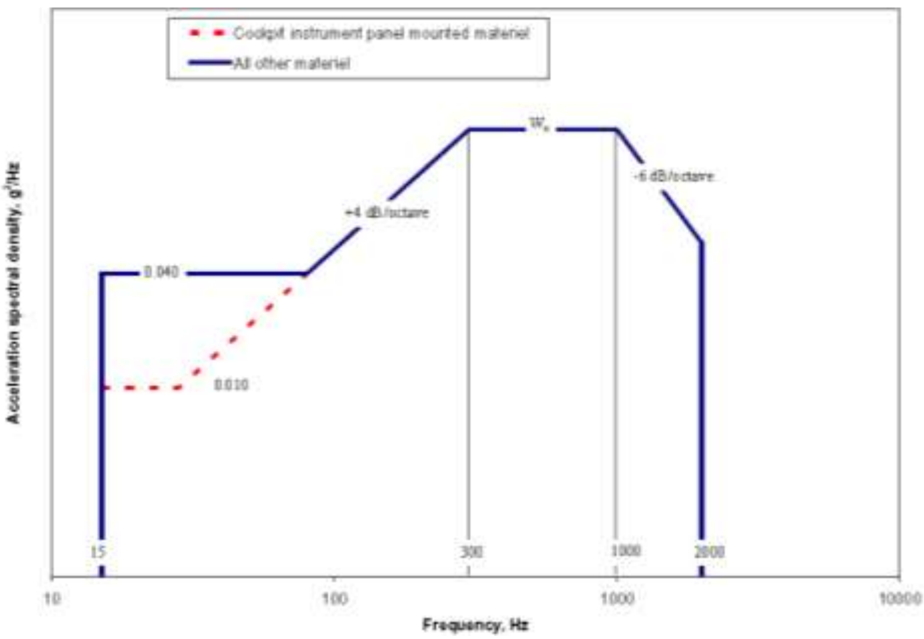

Figure 3: Random vibration profile in accordance with MIL-STD-810G

6.3 Results

Vibration test results are shown in Figure 4 and Figure 4. Two tests were carried out. The first test on unit SN 139956, and the second test on unit SN 139727.

Test 1

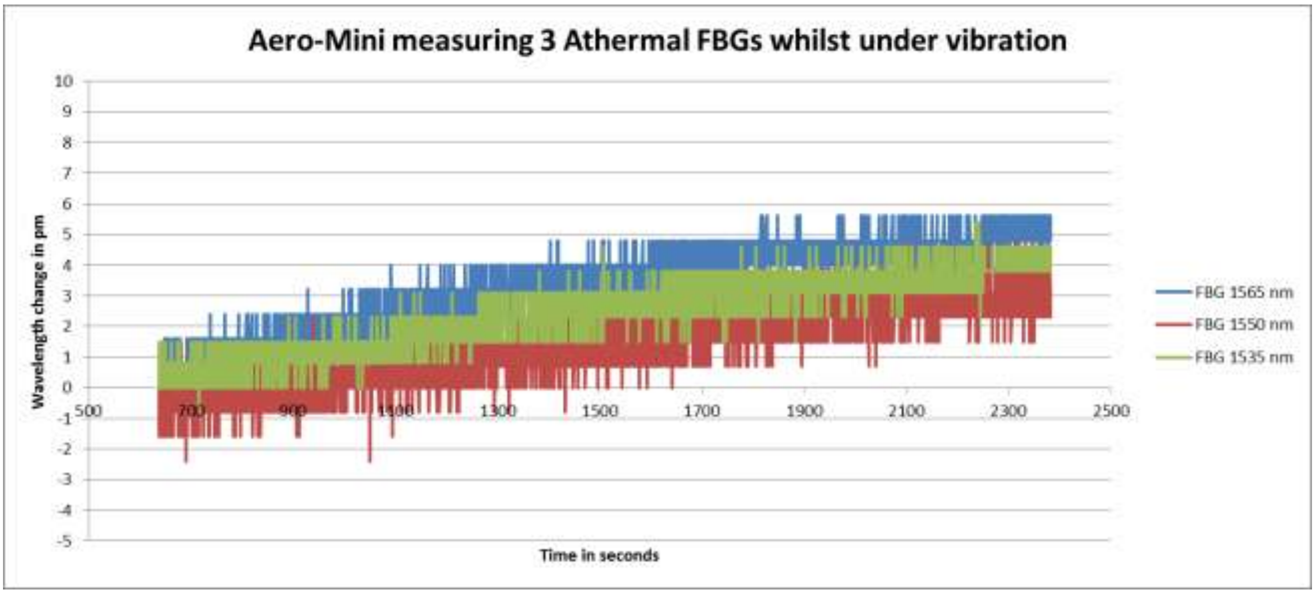

Figure 4: Change of 3 athermal FBGs logged by an Aero Mini under vibration

During the test the interrogator's performance was not influenced by vibration. The small increase in wavelength over the duration of the test is due the residual temperature sensitivity of the Athermal FBG test articles. The FBG wavelengths are within the UUT's ±5 pm specification.

Test 2

The test setup used in this test was identical to test 1 except that the test was applied on unit SN139727 and the Athermal FBG test articles were allowed time to settle at a stable temperature.

Figure 5 shows the resulting changes of the 3 athermal FBGs logged by the Aero mini during the vibration cycle (applied at 1.9hrs and lasting 30 minutes as per specifications). The wavelength stability during vibration test is well within the SmartScan aero mini specification of ±5 pm.

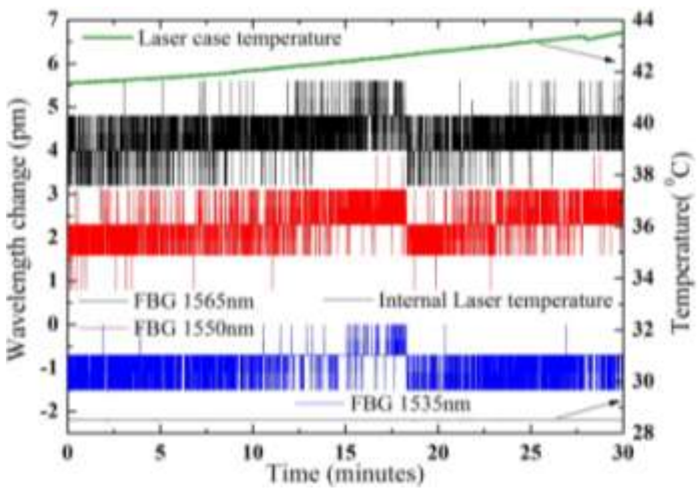

Figure 5: Wavelength stability of 3 athermal FBGs logged by an Aero Mini under vibration cycle

7 SHOCK TESTING

7.1 PROCEDURE

The shock testing setup was similar to the vibration test setup. The unit was fastened to the test fixture by its normal mounting means; an M6 screw through each of four designated holes at each corner. The test plate was in turn secured to the B&K shaker. The vibration and shock input was measured by an accelerometer mounted on the fixture close as possible to the test item.

The UUT was connected to three athermal FBG test articles connected in series on one of the fibre channels. These were not subject to vibration. Athermal FGBs have mechanical compensation to reduce their temperature dependency to close to 0 pm / ^{o}C. Wavelength data was recorded using SmartSoft.

The pulse profile was applied in incremental stages from 50%, to 75% and finally 4 pulses at 100%. Figure 6 shows the shock profile schedule saved on test setup control PC.

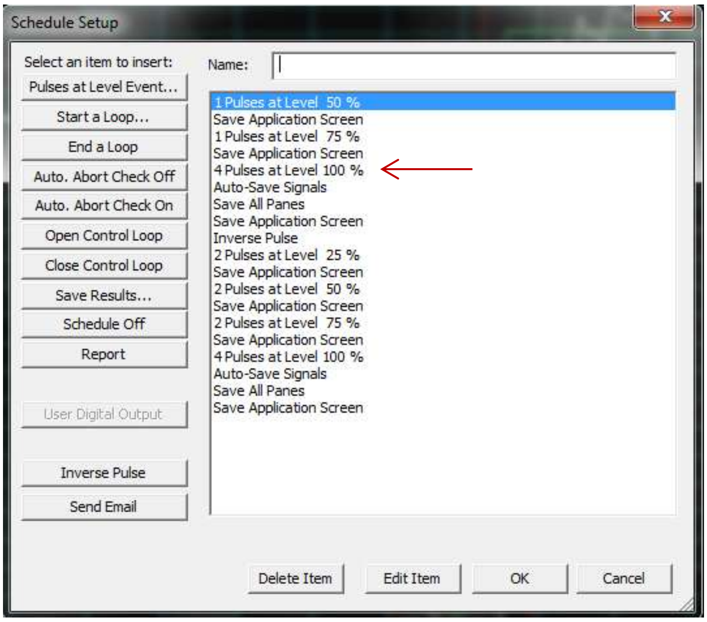

Figure 6: Default shock profile loaded on Vibration and Shock testing PC

7.2 SHOCK PROFILE

Shock testing was applied, in 1 axis, in accordance with MIL-STD 810G Method 516.6, Procedure I. The applied profile is shown in Figure 7, where T_D is the nominal duration in ms (for flight and ground vehicle equipment this is 11ms) and A_m is the minimum peak value in g's (for flight and ground vehicle equipment this is 20g and 40g, respectively).

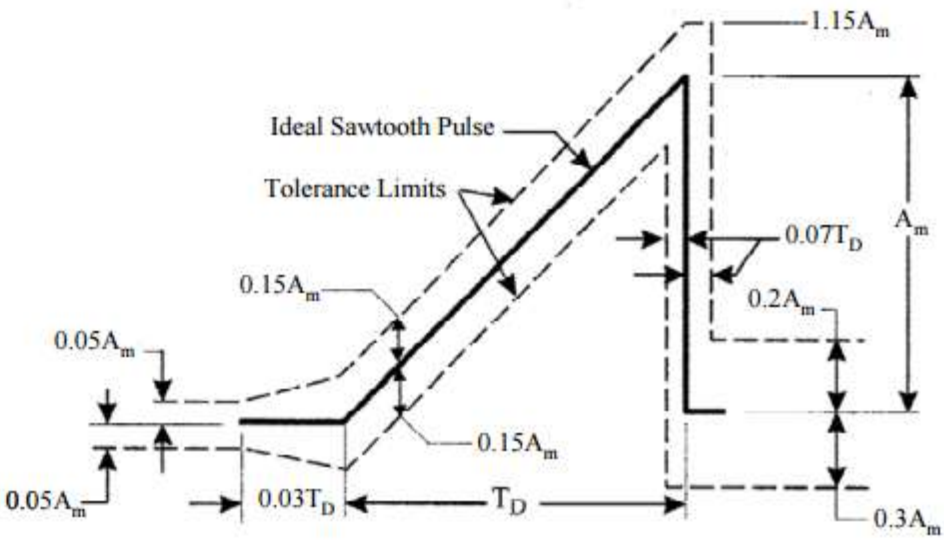

Figure 7: Terminal peak saw-tooth shock pulse configuration and its tolerance limits (Procedure I – Functional Shock, and Procedure V – Crash Hazard Shock Test).

RESULTS

The shock test record is shown in Figure 8. The test was applied on unit SN139727.

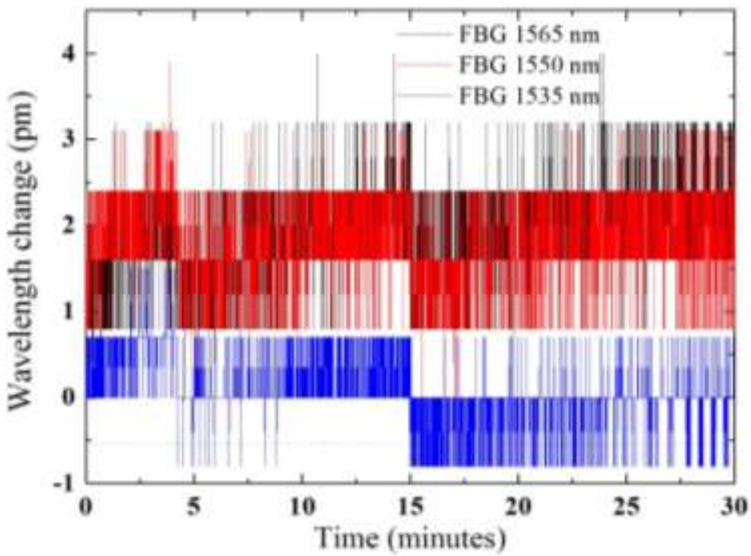

Figure 8: Wavelength stability of 3 athermal FBGs logged by an Aero Mini under shock testing

The results show the change in FBG reflection wavelengths logged by the Aero mini under shock testing and demonstrate that the SmartScan Aero-mini wavelength stability under shock testing is well within the specifications of ± 5pm.

8 TEMPERATURE RANGE

Two tests were carried out for the thermal cycling environmental testing of the Smart Scan Aero mini. The first test (Test 1) was on unit SN139956, and the second test (Test 2) on unit SN139727.

8.1 TEST 1 - PROCEDURE

The unit was placed in a climatic chamber and connected to the following equipment that was located outside the chamber: DC supply, 3 athermal FBG reference artefacts and a PC running SmartSoft acquisition Software. The chamber was programmed to go to certain set point temperatures across the operating range of the UUT. SmartSoft was used to monitor the FBGs and the Laser chip carrier and Laser case temperatures during the test. Additionally two K type thermocouples were placed between the two circuit boards inside the UUT and a third provided a reference measurement of the chamber temperature.

8.1.1 TEST 1 - TEMPERATURE PROFILE

At the start of the test the chamber was at room temperature, approximately 23 ^{o}C. The chamber was set to go to various temperatures and the UUT was allowed sufficient time to stabilize at each new temperature. The climatic cycling steps are given below in table 1.

Chamber set Point T ^{o}C	Time (s)	Stabilization Time (mins)
23	0 - 360	6
-20	360 -5800	90
-30	5800-8600	45
-40	8600-12500	65
+60	12500-17300	80

Table 1: Climatic chamber set points

8.1.2 TEST 1 - RESULTS

Table 2 summarises the temperatures at various points during the test, in chamber set point column arrows indicate when the set point was changed. The results from the data logged by SmartSoft are presented in Figure 9 below.

Time (s)	Chamber Set point (^{o}C)	Thermocouple Chamber (^{o}C)	Thermocouple A (^{o}C)	Thermocouple B (^{o}C)	Laser Case (^{o}C)
0	+23	+23	+27	+31	+32
360	↘ -20	+23	+32	+45	+33
5800	↘ -30	-20	0	+11	-0.5
7400	-30	-29	-5	+6	-3.1
8600	↘ -40	-30	-6	+5	-3.4
10000	-40	-35	-8	+2	-4.5
12500	↗ +60	-37	-9	0	-5.1
16000	+60	+60	69	+81	+69
16600	+60	+60	71	+84	+71
17300	+60	+60	71	+85	+72

Table 2: Summary of the data observed through thermal cycling

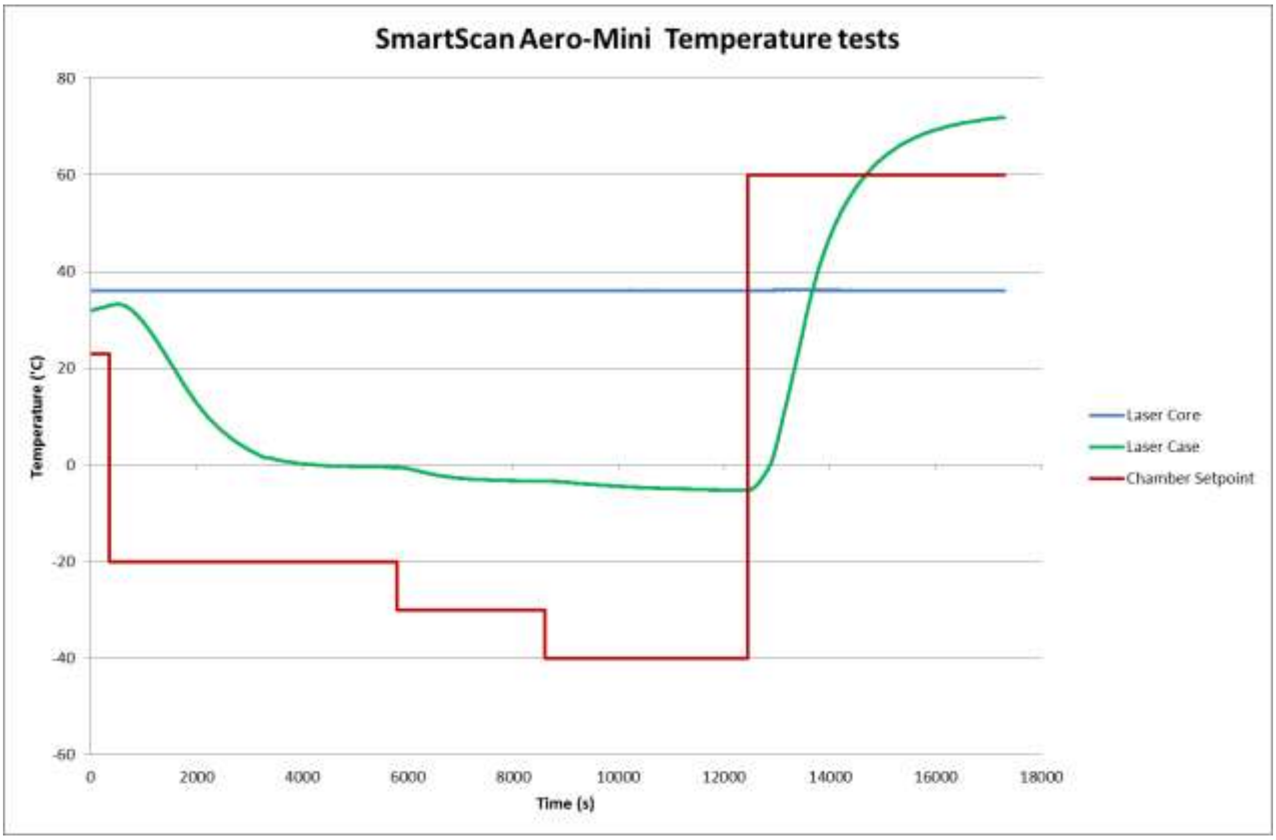

Figure 9: Results of SmartScan Aero mini thermal cycling of SN139956

During the tests the laser's chip carrier temperature remained stable, fluctuating only by <0.05 ^{o}C, this indicates that the SmartScan Aero-mini will perform within its measurement specifications over the operating temperature range tested, -37 to +60 ^{o}C.

The lower temperature of -37 ^{o}C was the minimum that could be achieved with SF's in-house climatic chamber.
Given that the UUT includes circuitry to prevent the Laser case temperature from falling below -10 ^{o}C it can be further surmised that performance would be maintained down to an external ambient of -55 ^{o}C, this needs to be validated by a further test at an external test house.

Further, the extremes of the internal temperatures measured by the thermocouples were between -9 and +85 ^{o}C. All the electronic and optical components within the SmartScan Aero-mini are rated for -40 to +85 ^{o}C operation. It is reasonable to expect the minimum internal temperature to be well above -40 ^{o}C when the external ambient is -55 ^{o}C.

8.2 Test 2 - Procedure

The UUT was placed in a climatic chamber and athermal FBGs were placed in a temperature controlled dry well. This ensured that any changes in their reflected wavelength would indicate that the UUT is being affected by the ambient temperature of the climatic chamber. The chamber was programmed to cycle between a minimum of -40 ^{0}C to maximum of 60 ^{0}C, and the UUT was allowed to stabilize at each new temperature point. SmartSoft was used to monitor the FBGs and the laser chip carrier and laser case temperatures during the test. Additionally two K type thermocouples were placed between the two circuit boards inside the UUT and a third provided a reference measurement of the chamber temperature.

8.2.1 TEST 2 - RESULTS

The results of the SmartScan Aero Mini thermal cycling are given by Figure 10 below.

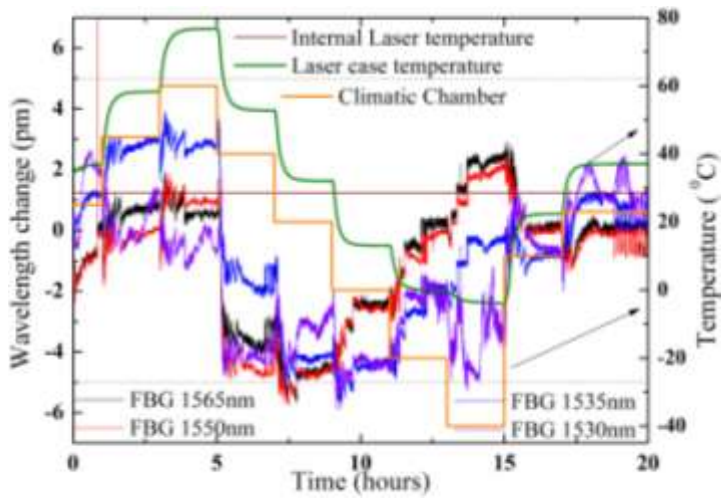

Figure 10: Results of SmartScan Aero mini thermal cycling of SN139727

Figure 10 shows that the laser chip carrier temperature remained stable over the cyclic range, with a fluctuating maximum of 0.05 ^{o}C. The change in wavelength of the three Athermal FBGs over the duration of the test at each temperature is expected due to the change in the interrogator temperature. However, the results show the SmartScan aero mini wavelength stability is within specifications of ± 5pm over the temperature range cycle.

9 CONCLUSIONS & FURTHER WORK

The Smart Scan Aero mini was subjected to environmental testing with respect to MIL-STD 810G standard. The results presented in sections 6 and 7 show stable performance with the interrogator maintaining its wavelength stability of ± 5pm in environments of vibration (with respect to MIL-STD 810G, Method 514.6, Annex D), and shock (with respect to MIL-STD 810G Method 516.6).

In the case of stable performance over the operating temperature range, it should be noted that the Smart Scan Aero mini data sheet specifies an operating temperature range of -15 ^{0}C to + 65 ^{0}C but the data presented has a minimum of -40 ^{0}C and a maximum of +60 ^{0}C. Hence, the product data sheet must be updated to have a temperature range of -40 ^{0}C to + 60 ^{0}C. With further testing at an external test house it is fully expected that -55 ^{0}C can be met because the SmartScan Aero-mini contains internal circuitry designed to maintain the laser within it rated operating temperature range as the outside temperature goes well below freezing.

It is not possible for the interrogator in its current format to reach the target upper ambient temperature of +70 ^{0}C. The enclosure and cooling design will need modification for this to be achieved.