

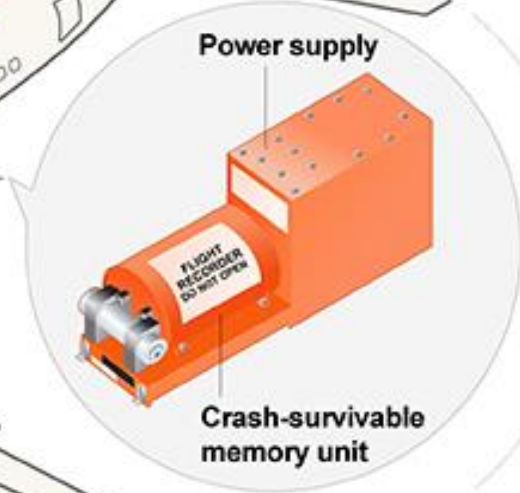
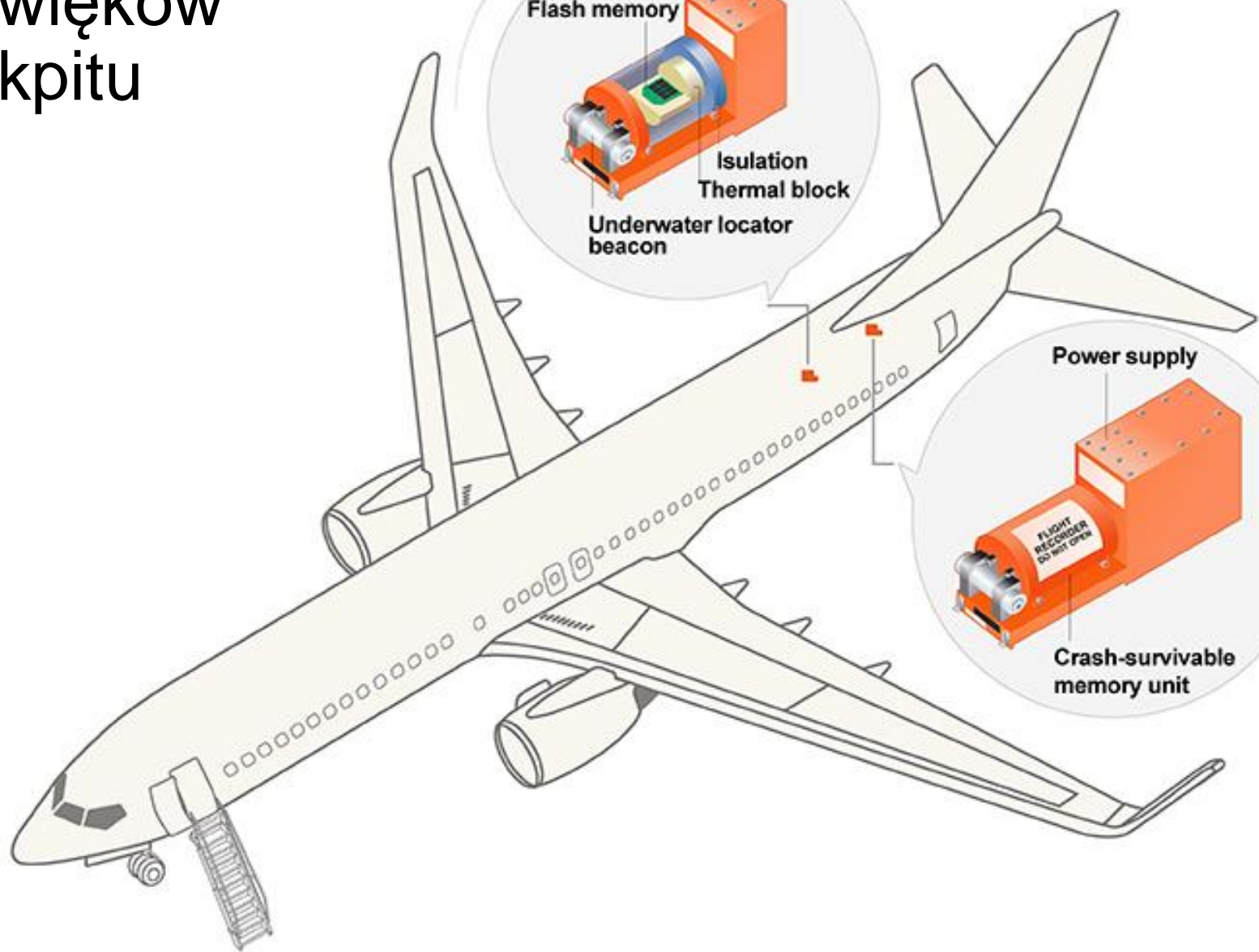
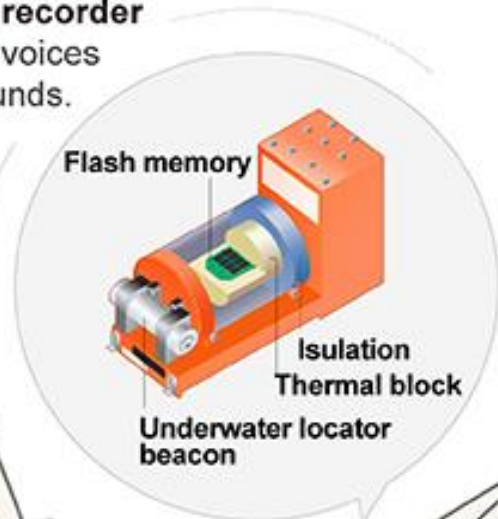
Odzyskiwanie danych z czarnej skrzynki

Łukasz Pietrzykowski



Rejestrator dźwięków kokpitu

Cockpit voice recorder
preserves pilot voices
and cockpit sounds.



Flight data recorder
captures such
information as altitude,
airspeed, heading and
engine thrust.

Rejestrator parametrów lotu

D.T.MUX Sentinel™



Crash Protected System
from 32 to 128GB



Reference#

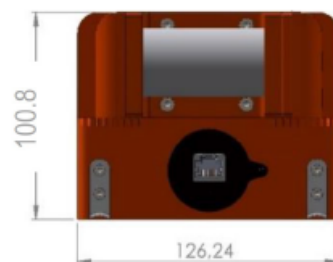
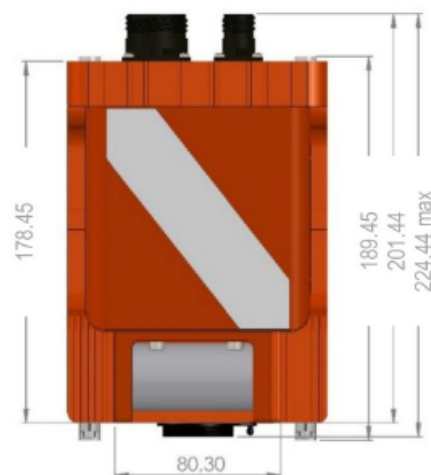
SEN-XXX





MECHANICAL

	Specification	Remark
Size	189.5 (231.8 iRIPS / 219.5 iEE) x 126.2 x 101 mm	D x W x H ± 1mm
Weight	≈ 3.30kg / 3.75kg ≈ 4.85kg	ED155/ ED112 iRIPS
Connectors	MIL-DTL-38999	Serie III
Mounting	ARINC 404	Customizable



ELECTRICAL

Input Voltage	28Vdc (16 to 36Vdc)
Power consumption	≈ 12 to 32 watts (28Vdc)
Power Interruption	≈ 200 to 800ms
Standard	MIL-STD-704F / DO-160

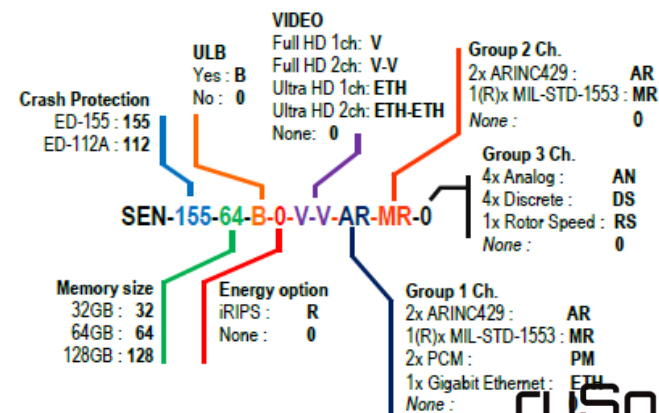
ENVIRONMENTAL

	Specification	Remark
Temperature	-40°C to 65°C	Operating
	-55°C to 90°C	Storage
Cooling	Passive	Convection
Humidity	95%	Non-Cond
Vibration	5Hz to 2KHz	6.29 g RMS
Shocks	20g 11ms	Operating
Acceleration	20g linear 3 axis	Operating
Altitude	+ 60,000 ft	Operating
Decompression	420Kpa/minute	Operating
MTBF	> 90,000 hours	Computed
EMI	DO-160	Rev G

STANDARD FUNCTIONALITY

	Specification
Gigabit	Configuration/Control
Ethernet	Data download and Streaming
Time synch	GPS Antenna input / Irig B / PTP v2
Voice	4x Audio channels
Recording	IRIG 106 Chapter 10 / DTMUX format
Sensors	Internal 3 Axis Gyro/ G force/ Pressure
COM port	RS-232 Configuration/Maintenance
Status	Status Led / Status output

SENTINEL PART NUMBER COMPOSITION



Environmental specifications

Environmental specifications

The equipment has been designed to meet the environmental specifications applicable to the installation limits as set forth in the version of RTCA/DO-160 in force at the time of certification.

Flight Recording Systems (ED-112), Survivability

- Impact: 3400 Gs, 6.5ms, All Axes
- Pin Penetration: 500 lb., 10 ft. (1/4 in. Pin)
- Static Crush: 5000 lb, 5 min All Axes
- Low Temp Fire: 260°C, during 10 hours
- High Temp Fire: 1,100°C, during 60 Min
- Sea Water Immersion: 30 Days
- Deep Sea Pressure: 20,000 ft., 24 Hrs.
- Fluid Immersion: Various Fluids, 48 Hrs.

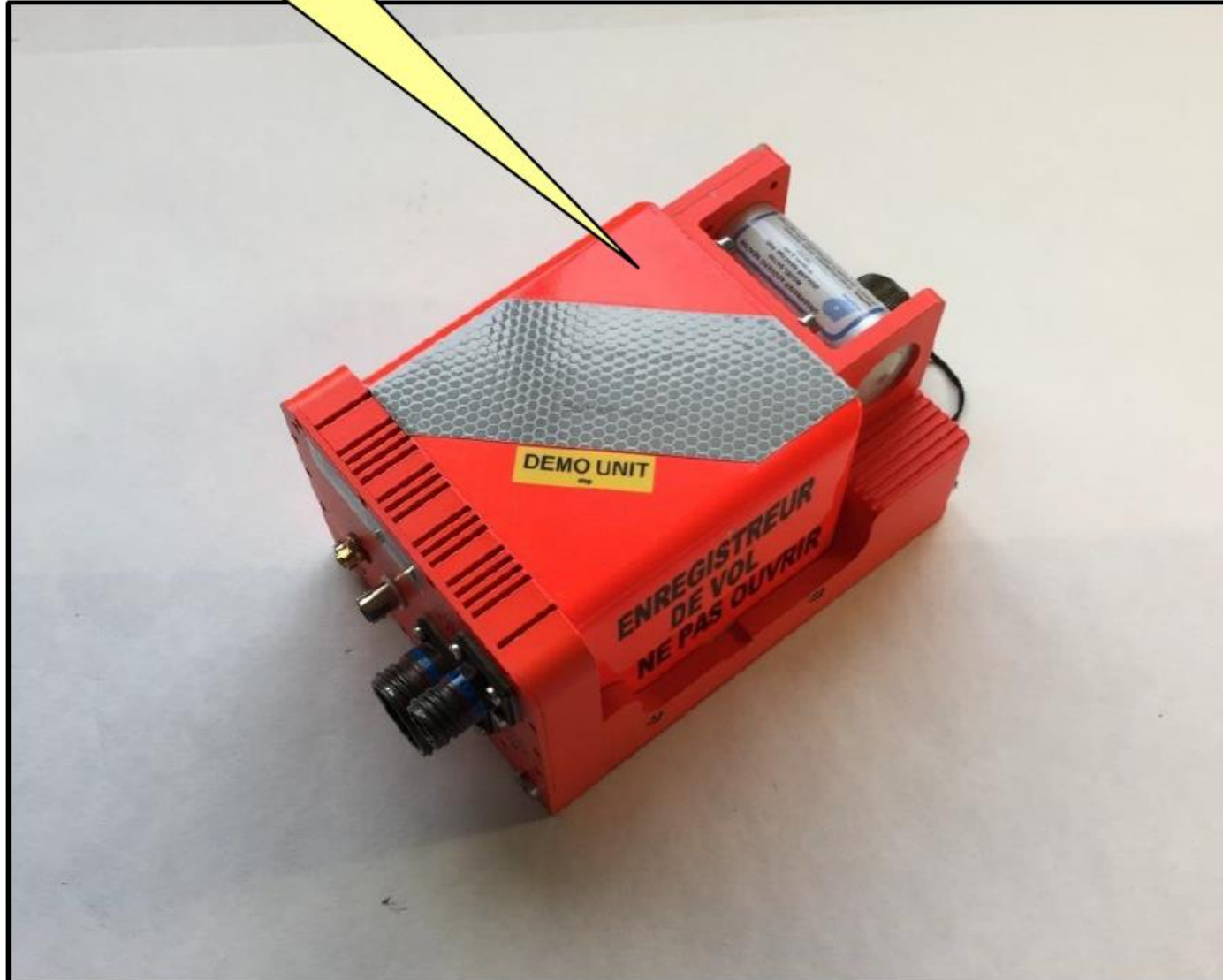
Qualification/Certification

Sentinel "ED-112 type" meets the requirements as specified in the Minimum Operational Performance Specification (MOPS) for flight recording systems ED-112. The system also outperforms many of the crash survival requirements in the Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems ED-112.



Sentinel Under High temperature fire test

Crash Protected
Memory Block



Testy przeciążeniowe – nacisk prasy hydraulicznej pod różnymi kątami



Diagonal 1



Diagonal 2



Diagonal 3



Diagonal 4

Testy zderzeniowe



pSi-19-1386, ETEP- Impact Shock Test 02 B X+

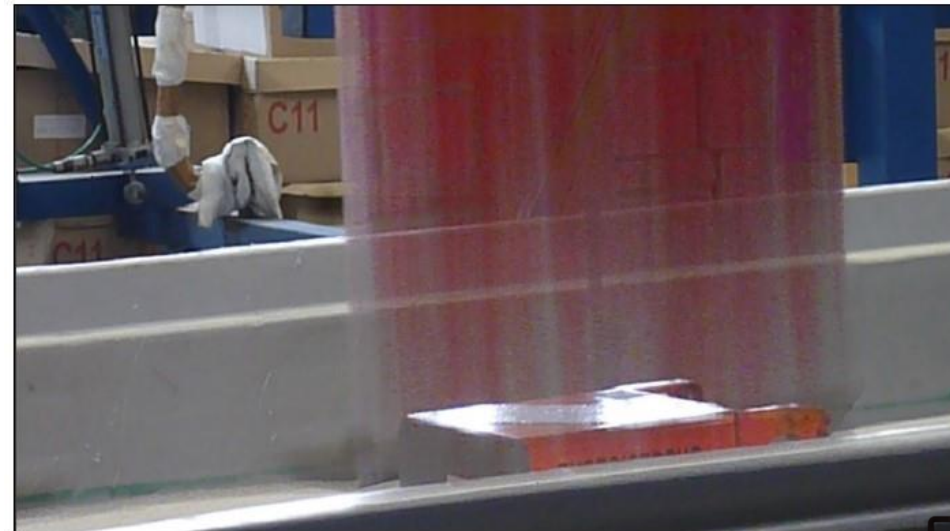
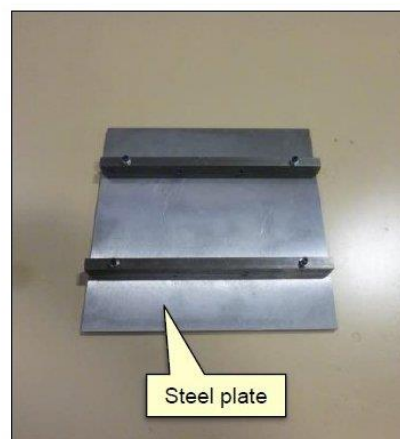
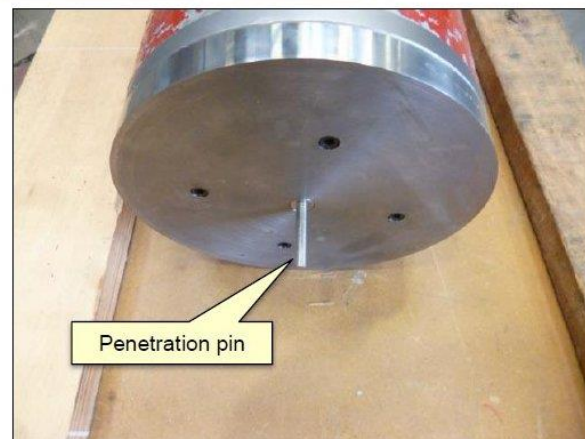
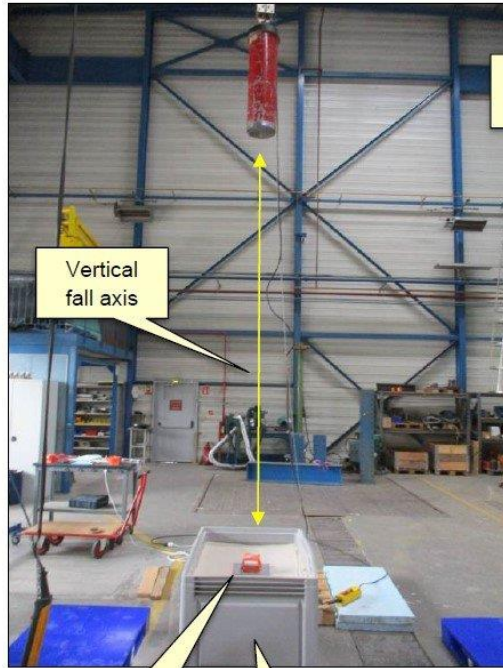


pSi-19-1386, ETEP- Impact Shock Test 02 B X+



pSi-19-1386, ETEP- Impact Shock Test 02 B X+

Próby uderzeniowe



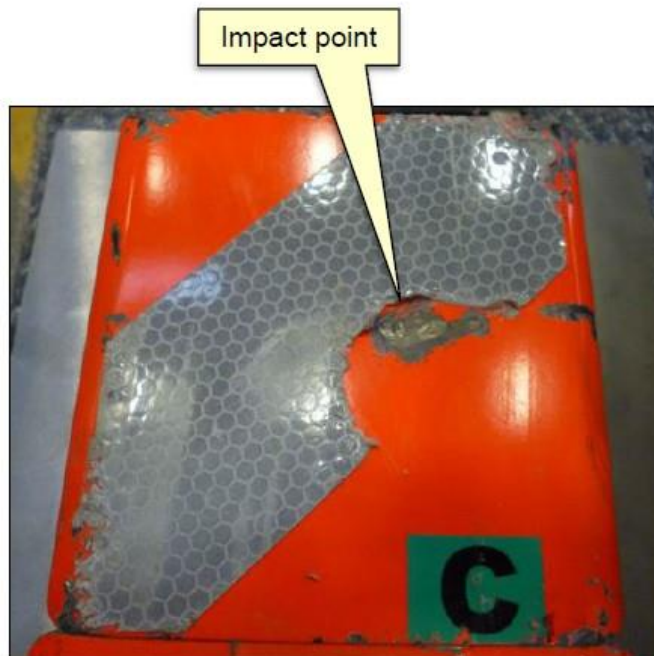
Mechaniczne uszkodzenia po testach



CSMU "A", "B" and "C" has successfully pass test sequence, no penetration or deformation of structure has been noted for each one.

Note:

Data contained inside robust memory are not analyzed before end of test sequence.





IFREMER is a French institute that undertakes research and expert assessments to advance knowledge on the oceans and their resources, monitor the marine environment and foster the sustainable development of maritime activities.

For more information consult Ifremer website:
<https://wwz.ifremer.fr/en/>

The Sentinel CPM is placed in hyperbaric chamber during 24 hours at 625 Bar, in saltwater to simulate a depth of 6000m. The materials used to protect the recording medium have been shown to be unaffected by sea water (Titanium ...)



Testy wysokociśnieniowe

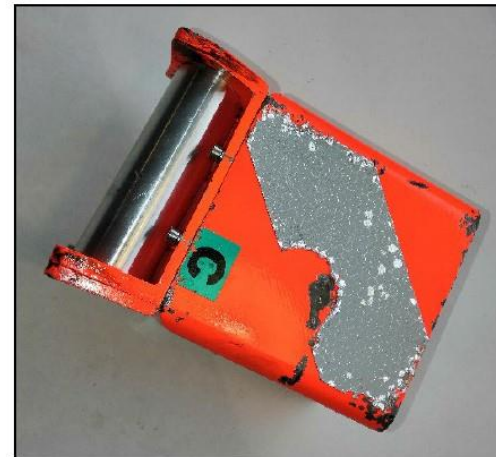
Sentinel CSMU Structure



This test must determine if the crash protected memory Sentinel can resist to an equivalent depth of 6 000 m (20 000 feet).

We no detected any change of the Sentinel CPM structure after 24 hours at 625 Bar.

After this test in laboratory we don't note any deformation of the structure, and the structure is remains in **full integrity**.



Testy temperaturowe



Test has been conducted on Crash Protected memory unit destined to equip Sentinel System. The fire test is started by turning on the main gas valve. Flame temperature, as indicated by the external thermocouples, is continuously monitored. Figure 2 picture show Crash Protected Memory module under high temperature test.

At the end of the test period, the burners have been shut off and the robust memory module has been cool naturally in ambient conditions. The crash Protect memory unit has been removed from the vicinity of the support arrangement.

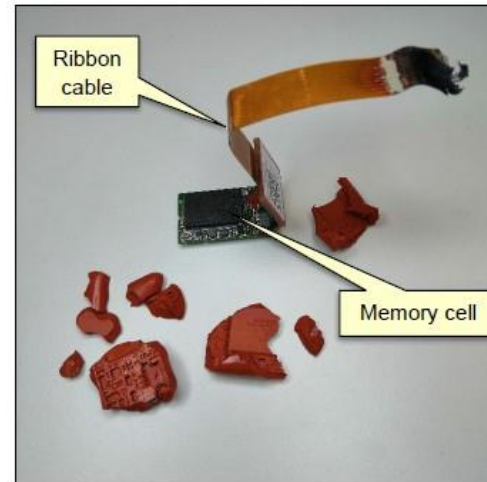
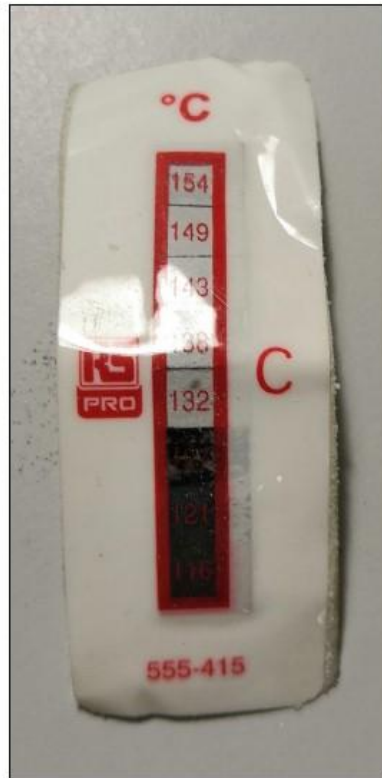
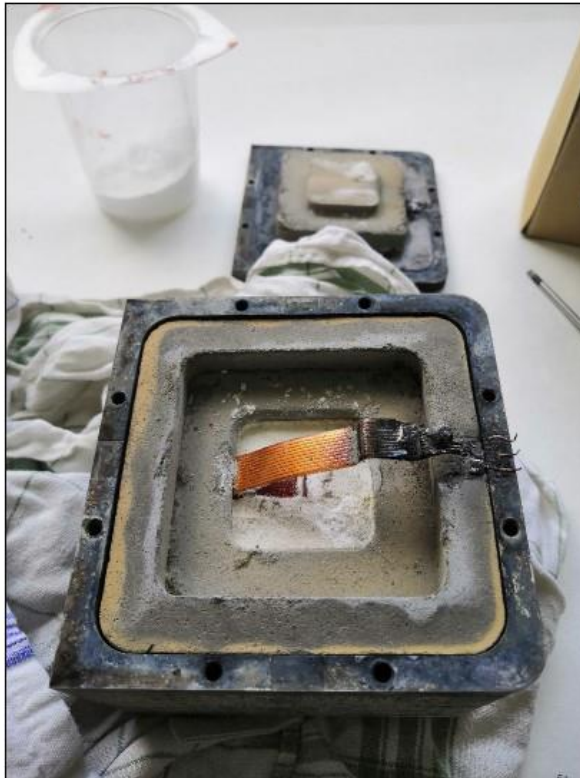
Testy temperaturowe - wyniki



The unit is progressively put back to room temperature (natural cooling) the time is approximately 3 hours before being able to go for opening process.

we don't notice any deformation of the structure and the structure is in **full integrity**. Bright orange paint has disappeared.

Reached temperature inside enclosure up to 132°C



After the test sequence has been performed, this test pattern shall be readily recoverable to establish that the bit error rate defined in Chapter 2-4 has not been exceeded.

After this test the Sentinel crash protected memory is open to verify if the PCB did not damaged and if the data is still readable. After remove of all insulation protection (Ceramic, white powder material and red silicon protection), we examine the memory PCB.

Solid state drive integrity

After a visual inspection, we no detect any damages on solid state drive circuit.

The memory unit was tested to verify if the data is in full integrity.

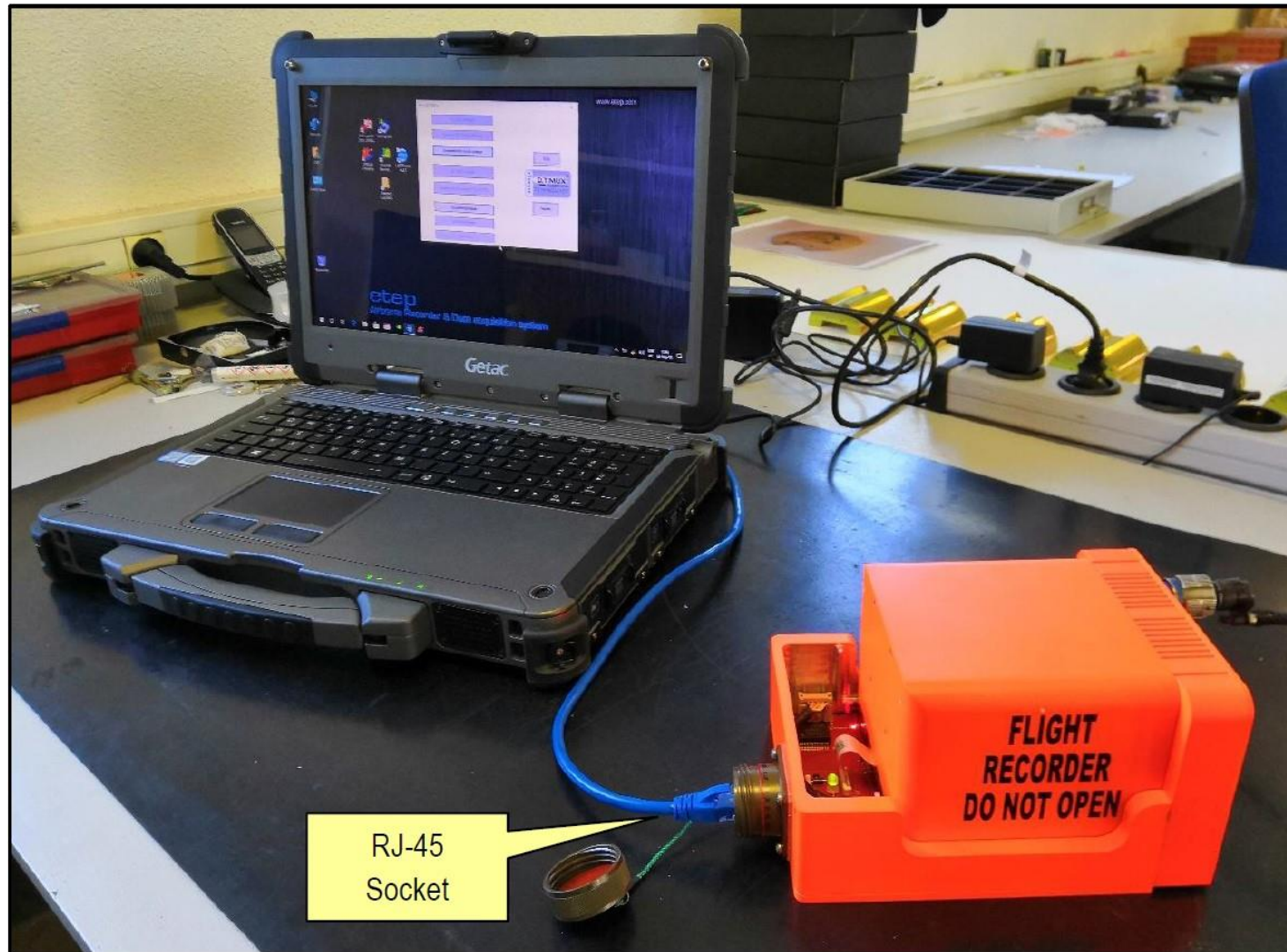
The data is in full integrity and no present any error.

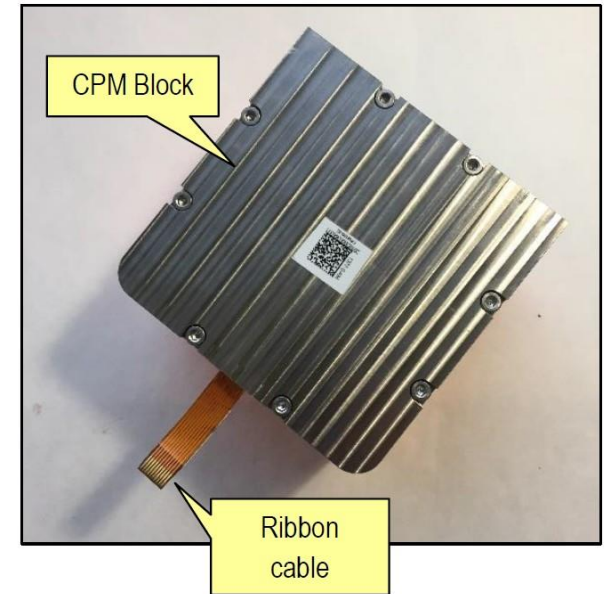
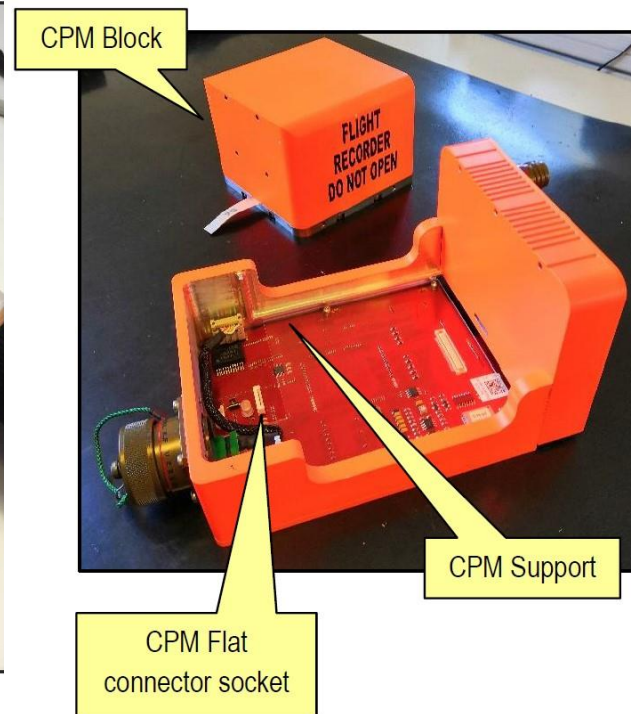
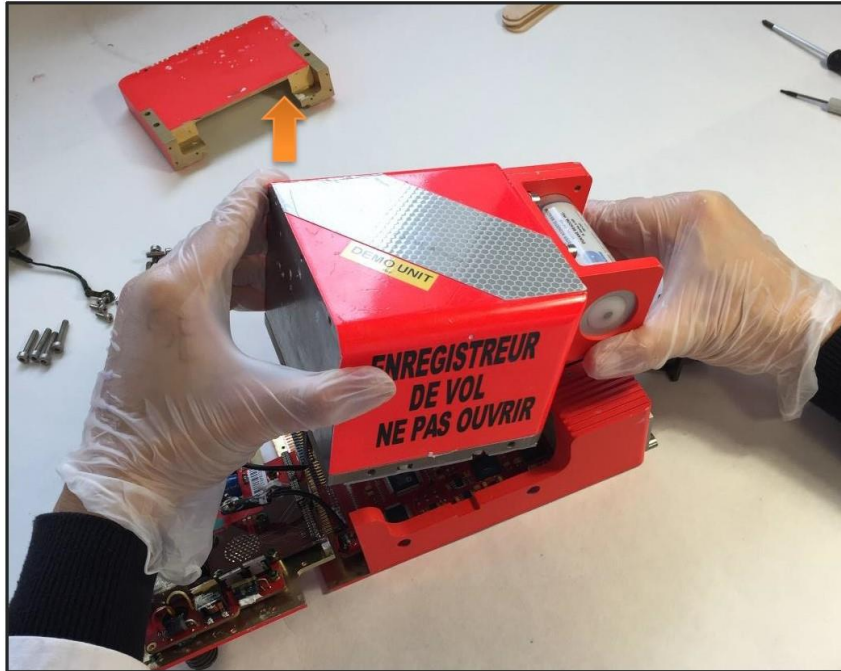
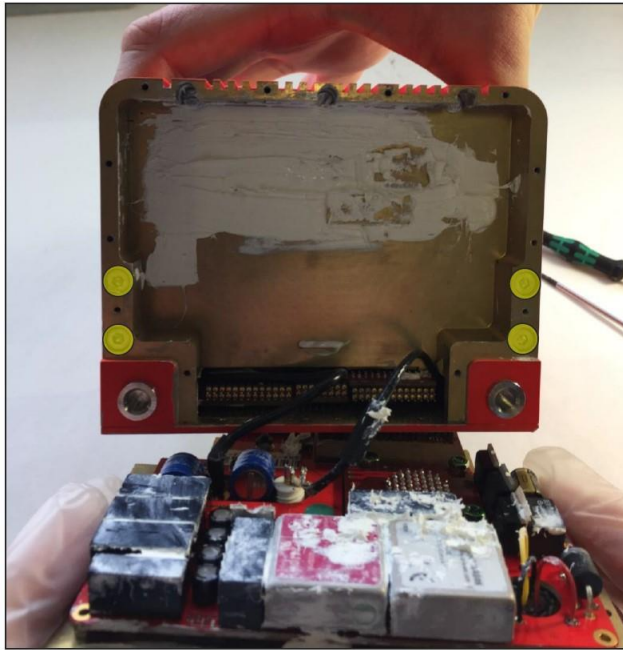
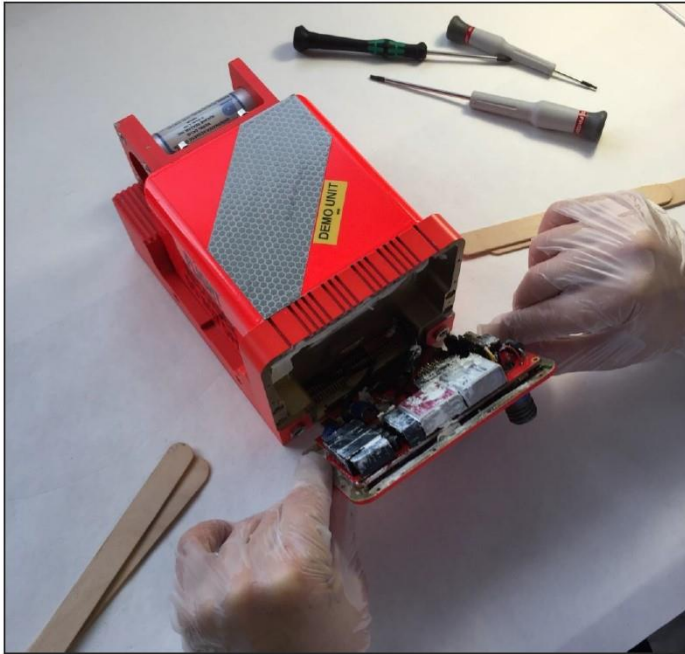
The screenshot shows the ETEP software interface for verifying a DTMUX IRIG106 format. The interface includes a file selection step (1), a directory for log files (2), and a verification table (5). The verification table shows the following results:

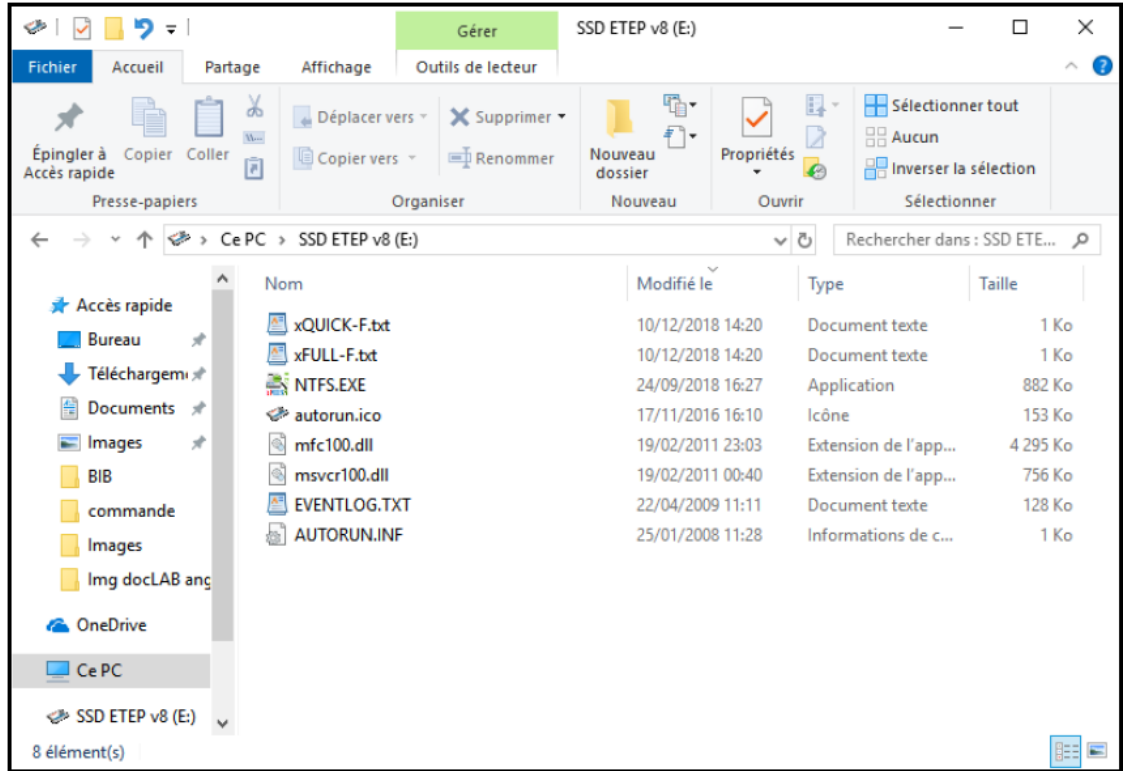
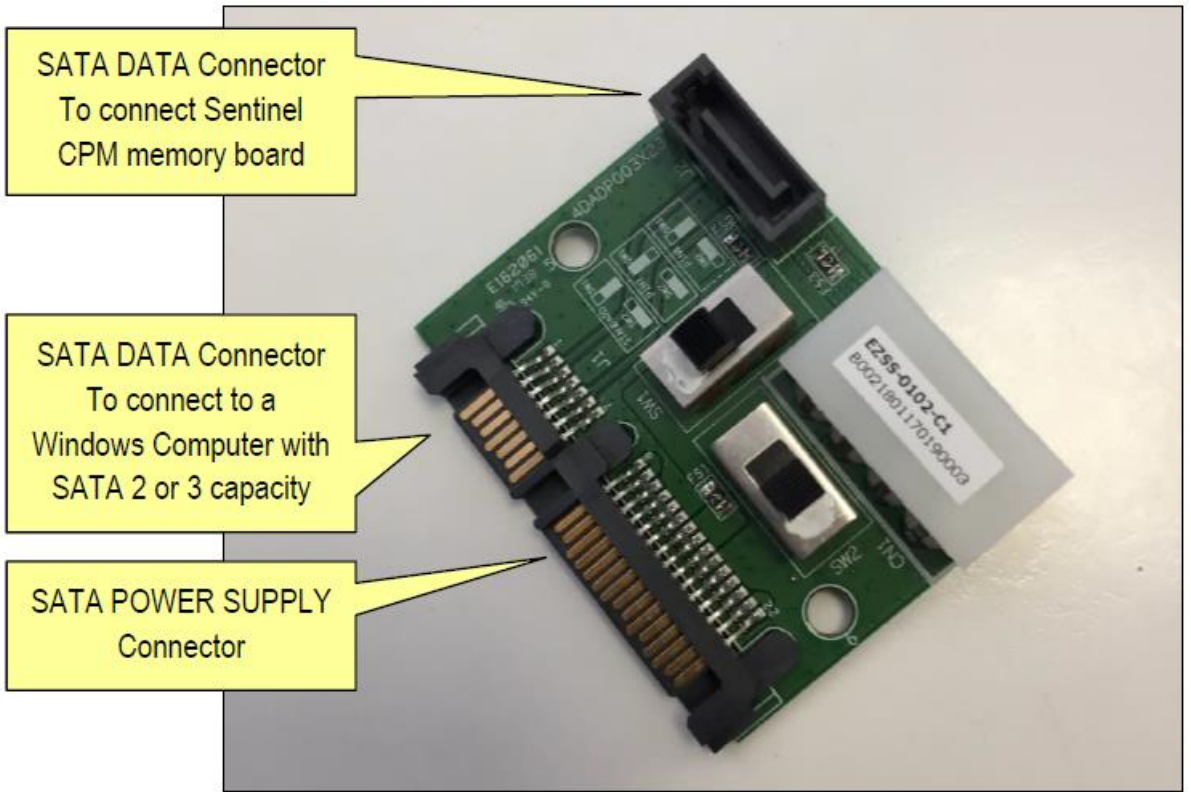
ERROR	VALUE
ERROR KEY	0
ERROR STRUCTURE	0
ERROR TIME	0
ERROR BLK	0
ERROR CARD ID-TYPE	0
ERROR CH-WC-WCU	0
WARNING EMPTY CHANNELS	2
ERROR UNEXPECTED CH	0

The interface also shows a progress bar for the verification process and a status bar at the bottom indicating the results for each channel (CH).

Kopiowanie danych poprzez zewnętrzny interface



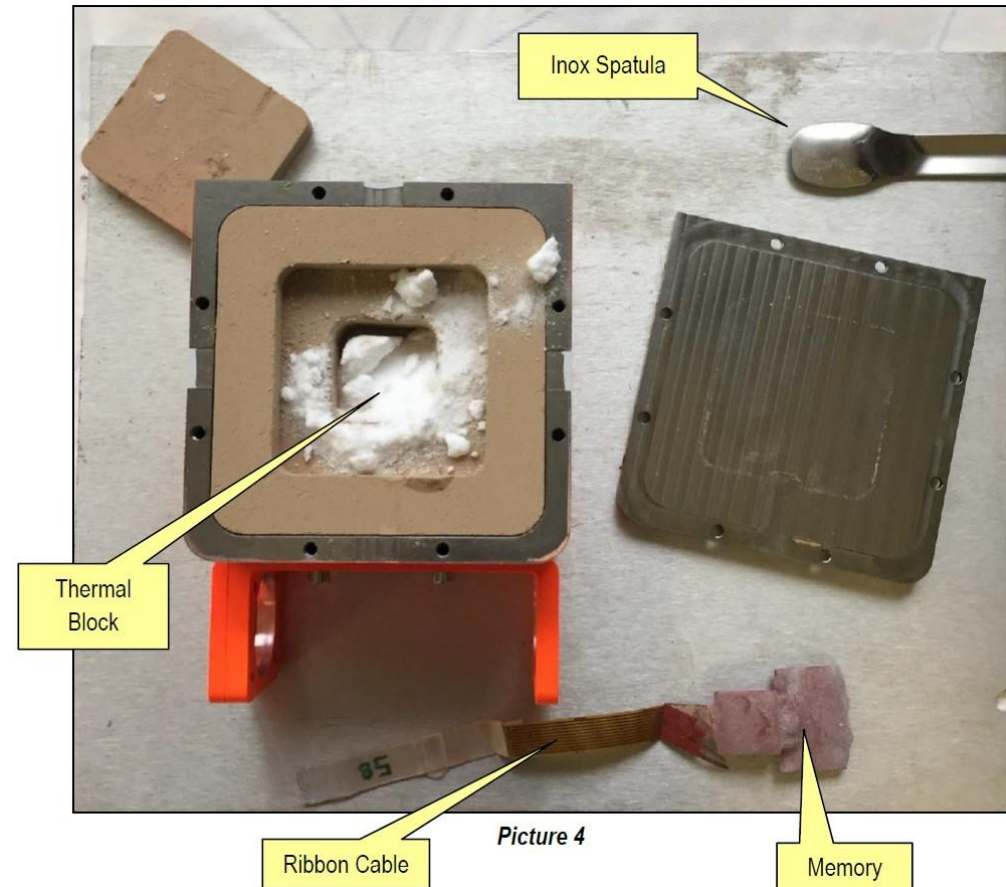
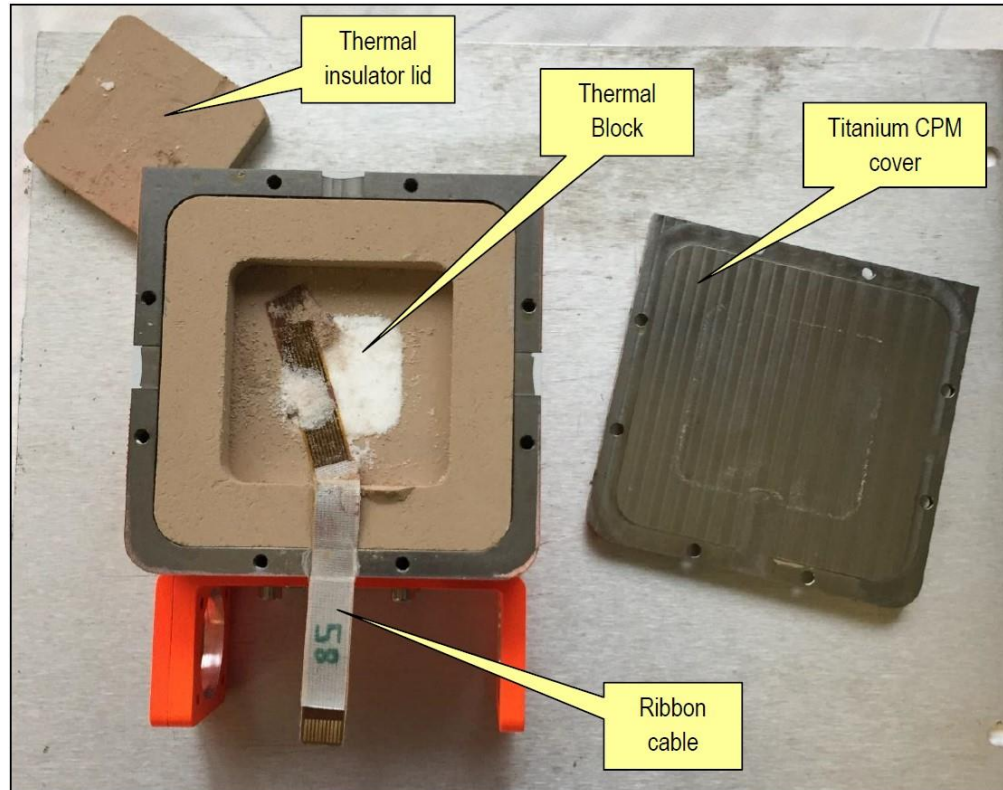


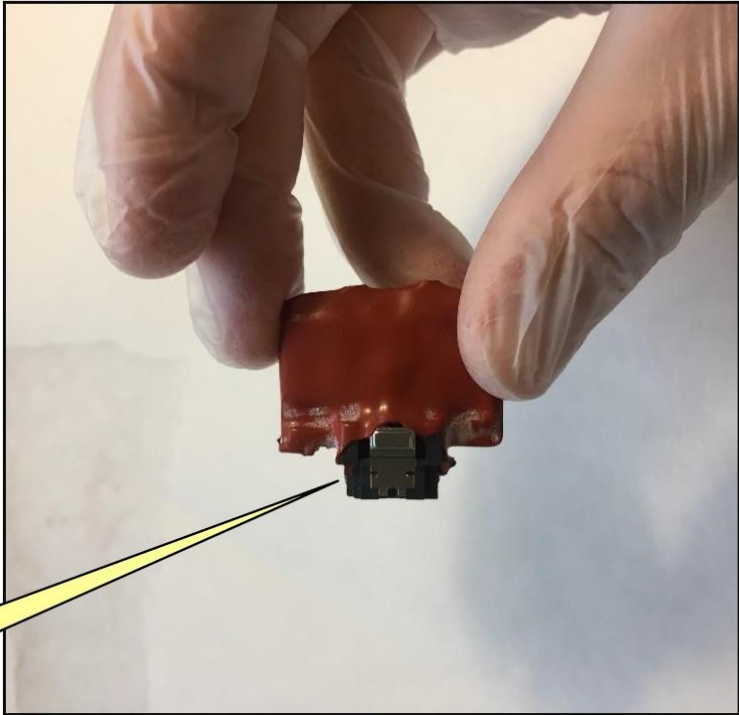
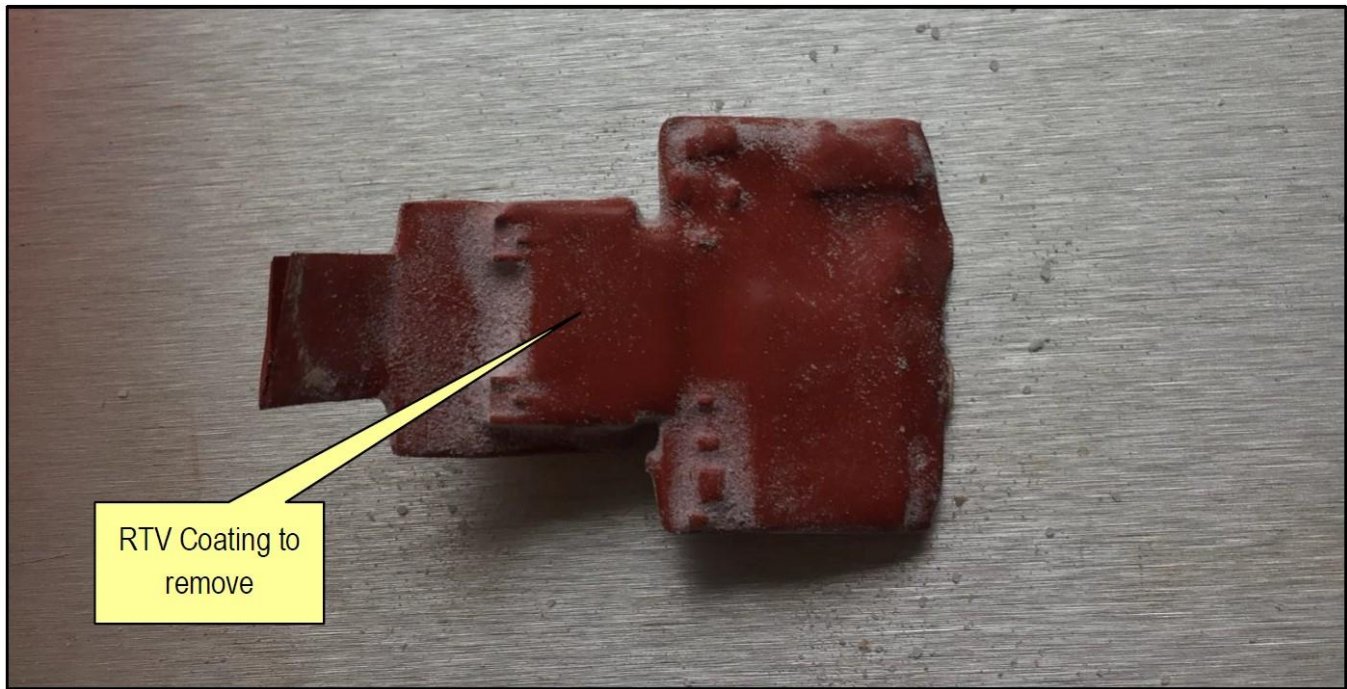


Realne testy...

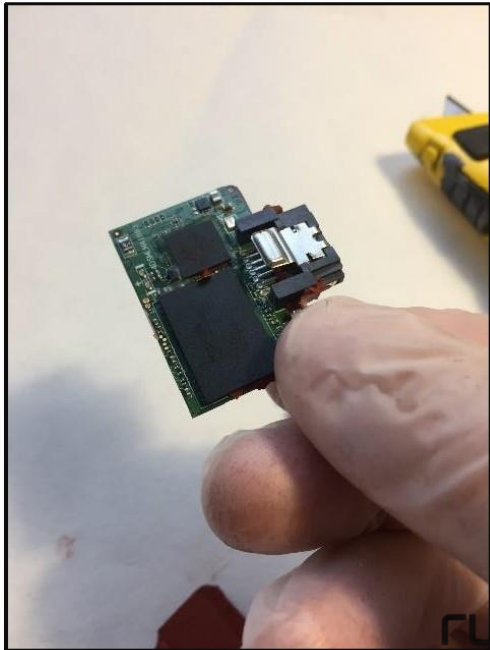
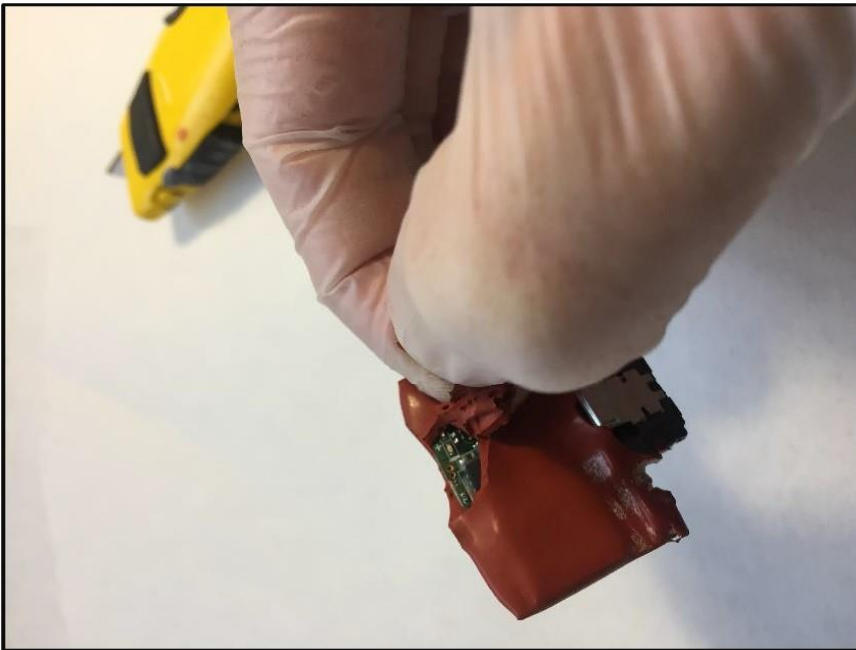


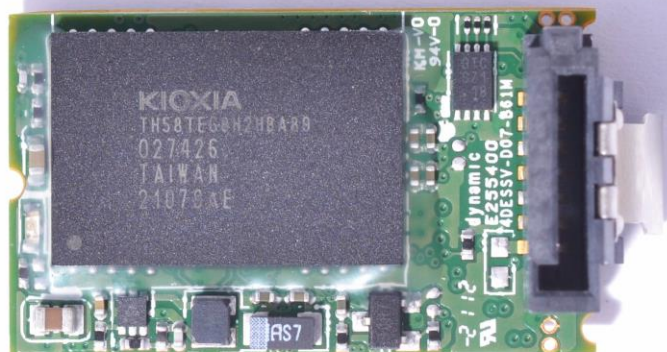
Wydobycie modułu pamięci





SZCZĘŚLIWIE, katastrofy i uszkodzenia z nimi związane są niezwykle rzadkie, nie zdobyliśmy uszkodzonego urządzenia





Na drugiej stronie PCB umiejscowiony jest mikrokontroler firmy Innodisk model (rodzina modeli) ID107

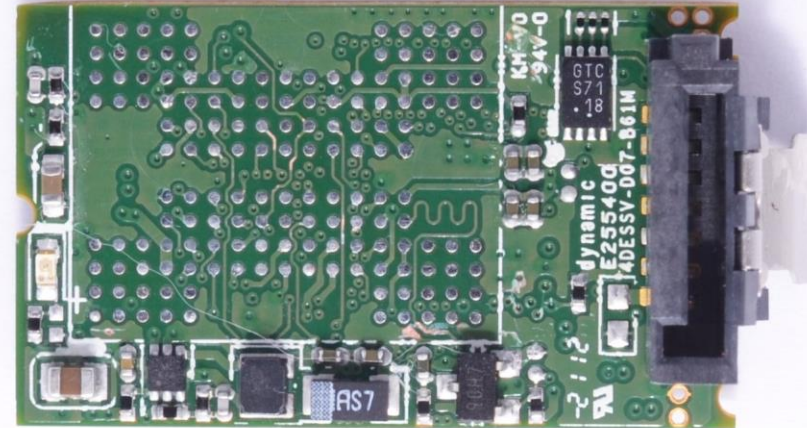


Na tej stronie płytki drukowanej widoczny jest chip pamięci NAND wyprodukowany przez Kioxia (Toshiba), nazwa modelu: TH58TEG8H2HBA-89

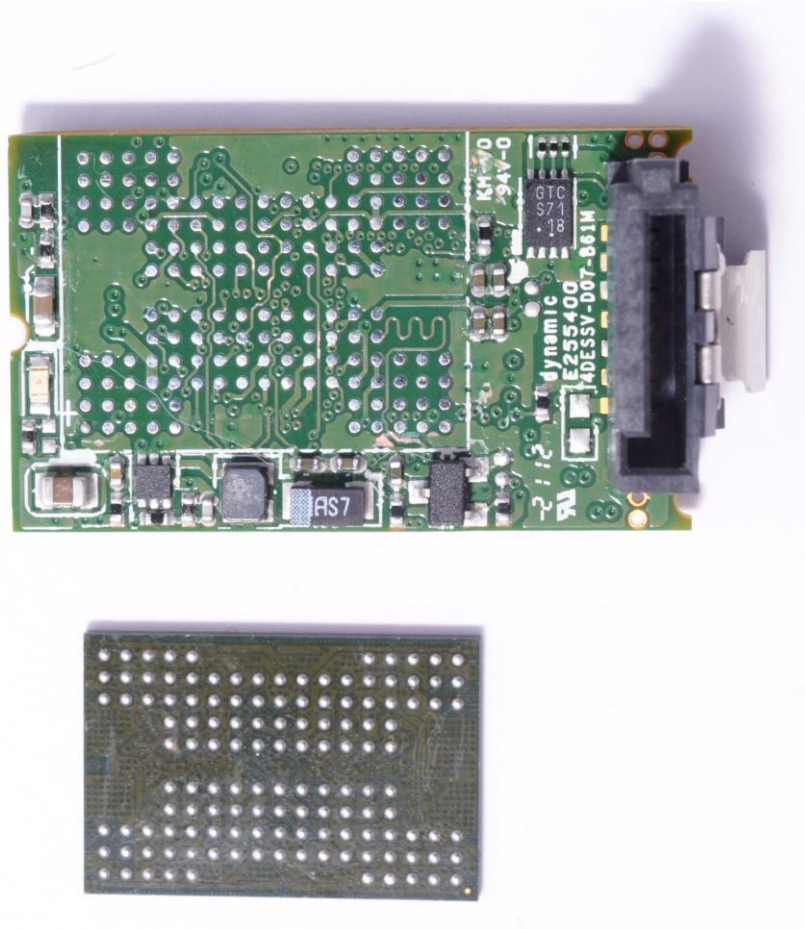


Zdemontowany chip NAND – widok z góry

Aby uzyskać dane bezpośrednio z pamięci NAND, konieczne jest wylutowanie chip'a za pomocą stacji na podczerwień przy parametrach $T_{max} = 240C$ ($T_{delta} \sim 3C/s$)



Zdemontowany chip NAND – widok z dołu (od strony padów)



Układ pamięci to chip BGA-132 i jest rodzaj często spotykany w większych pamięciach.

Pady pamięci zostały wyczyszczone knotem lutowniczym (solder wick) po czym alkoholem izopropylowym

Chip podłączony do czytnika VNR

Odczyt pamięci został wykonany za pomocą czytnika Visual Nand Reconstructor z zestawu startowego przy użyciu adaptera BGA132 który z kolei jest częścią zestawu Standard.



Chip identification

Select configuration

	Data bus 0	Data bus 1
CE0	<input checked="" type="checkbox"/> 98DEA1327AD60808 WP Ready	<input type="checkbox"/> 0000000000000000
CE1	<input checked="" type="checkbox"/> 98DEA1327AD60808 WP Ready	<input type="checkbox"/> 0000000000000000
CE2	<input type="checkbox"/> 0000000000000000	<input type="checkbox"/> 0000000000000000
CE3	<input type="checkbox"/> 0000000000000000	<input type="checkbox"/> 0000000000000000

Configuration

Model filter: 98DEA1327A

Model	Identifier	Source
-------	------------	--------

Model: TH58TEG8H2HBA89
Vendor: TOSHIBA
Identifier: 98DEA1327A

Speed: High
Power (Vcc): 3,3 V
I/O Power (VccQ): 3,3 V
Bus: 8 bit
Pinout: ONFI
Signals: VSP3 VSP2 VSP1 WP

Page size: Nominal: Real: 9216 bytes

Block size: 1179648
Plane size: 9663676416
Planes: 2
Protocol: Async DDR
 Sandisk/Toshiba VSC

Power up actions:

Reread ID Apply configuration Cancel

W pierwszej kolejności wymagany jest odczyt ID pamięci NAND.

Identyfikator 98DEA1327A należy do pamięci wyprodukowanej przez Toshiba/Kioxia

W tym układzie znajdowały się 4 płaszczyzny/kryształy.

JEDEC data

Select configuration

Chips	JEDEC
Parameter page signature	JESD
Revision number	supports vendor specific parameter page
Features supported	no
Optional commands supported	no
Secondary commands supported	no
Number of parameter pages	0x0
Device manufacturer	TOSHIBA
Device model	TH58TEG8H2HBA89
JEDEC manufacturer ID	000000000098
Number of data bytes per page	0x2000
Number of spare bytes per page	0x400
Number of pages per block	0x80
Number of blocks per logical unit (LUN)	0x103C
Number of logical units (LUNs)	0x2
Number of Address Cycles	row 0x3, column 0x2
Number of bits per cell	0x1
Number of programs per page	0x0
Multi-plane addressing	0x1 bits for plane address
Multi-plane operation attributes	no
Asynchronous SDR speed grade	no
Toggle Mode DDR and NV-DDR2 speed grade	supports 30 ns speed grade (~33 MHz) supports 25 ns speed grade (40 MHz) supports 15 ns speed grade (~66 MHz) supports 12 ns speed grade (~83 MHz) supports 10 ns speed grade (100 MHz) supports 7.5 ns speed grade (~133 MHz) supports 6 ns speed grade (~166 MHz) supports 5 ns speed grade (200 MHz)
Synchronous DDR speed grade	no
Asynchronous SDR features	0x0
Toggle-mode DDR features	0x0
Synchronous DDR features	no
Maximum page program time (tPROG)	0 us
Maximum block erase time (tBERS)	0 us

Reread ID

Apply configuration Cancel

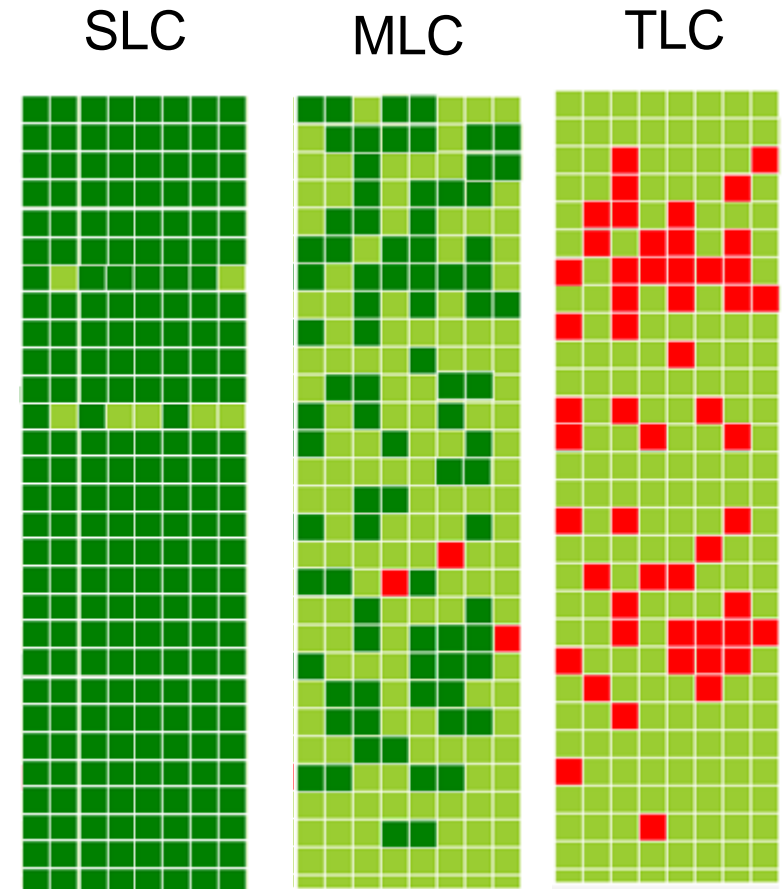
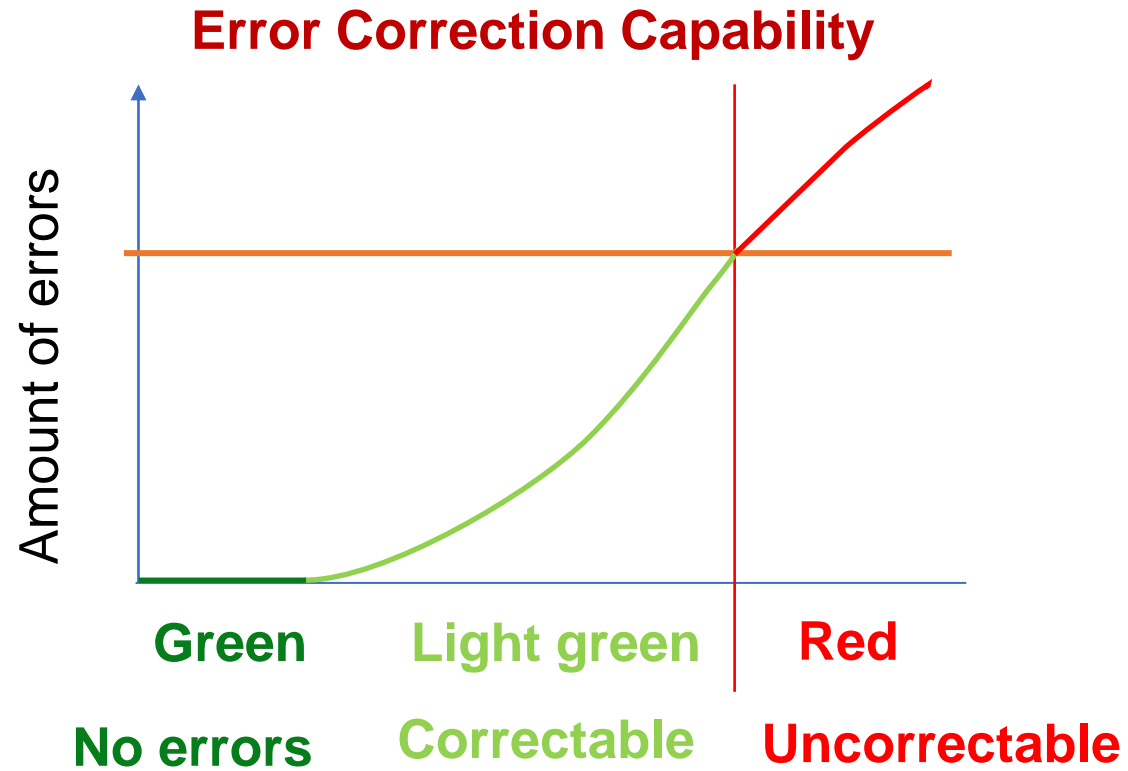
Przy odczycie ID, zostały także wyczytane parametry JEDEC, które dostarczają podstawowych informacji na temat układu.

Jedną z informacji jest liczba bitów na komórkę:

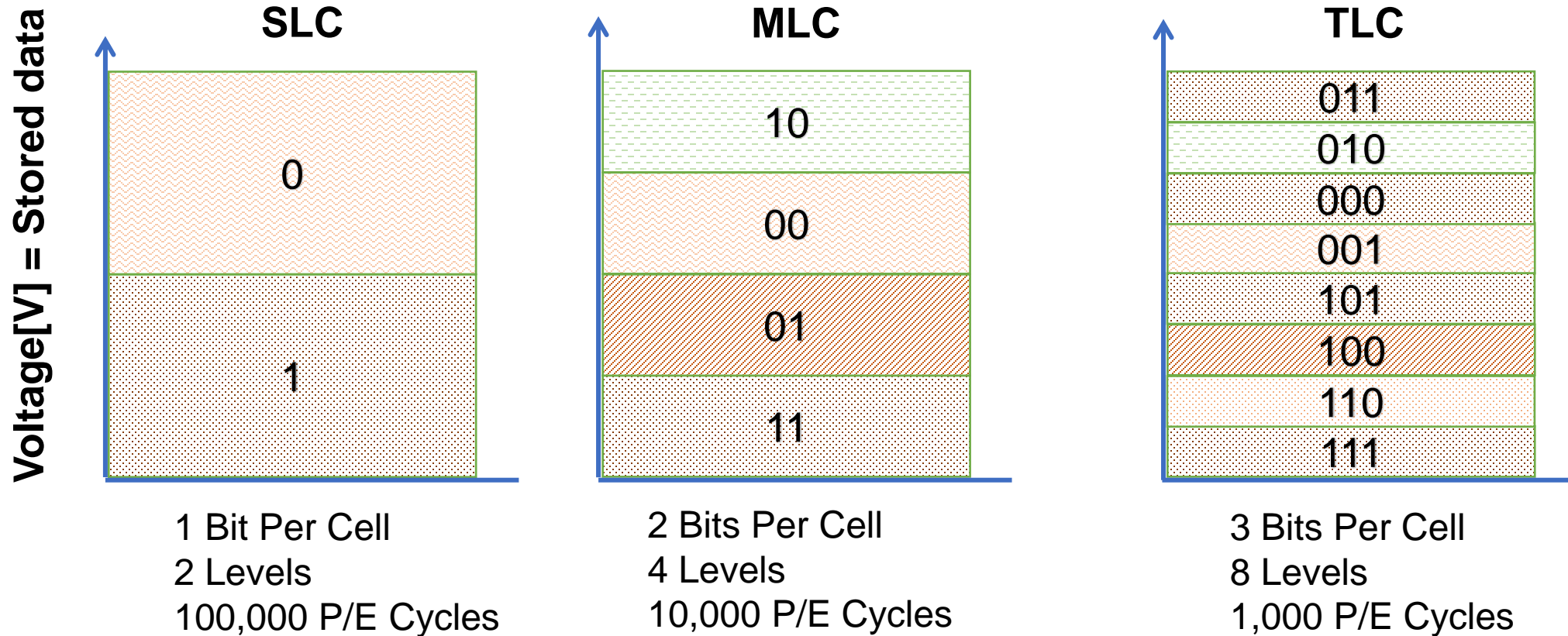
“Number of bits per cell = 1”,

Oznacza to, że pamięć posiada architekturę SLC, co jest kluczowym parametrem dla stabilności zapisanych danych.

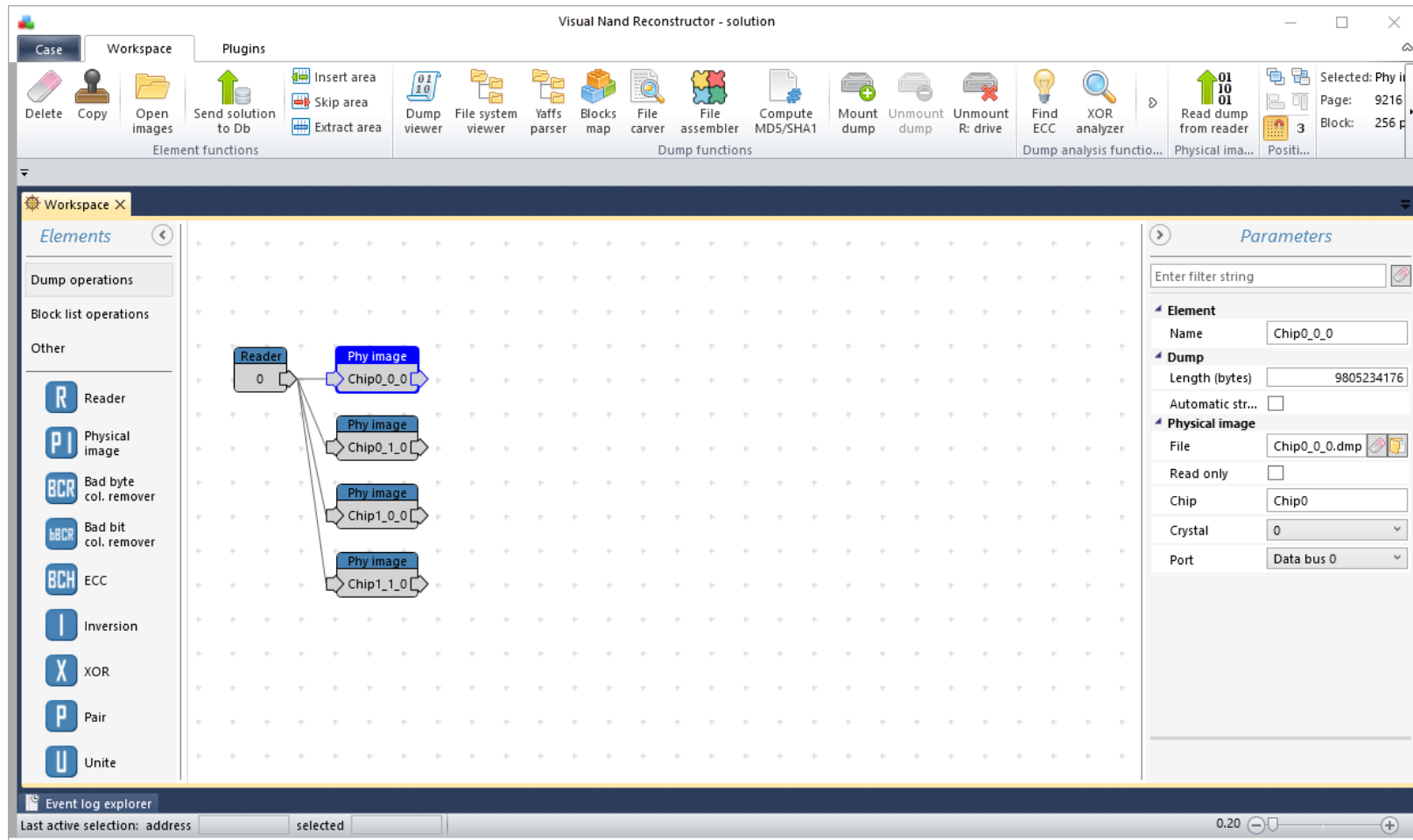
Błędy bitowe w NAND



Architektura komórek pamięci NAND



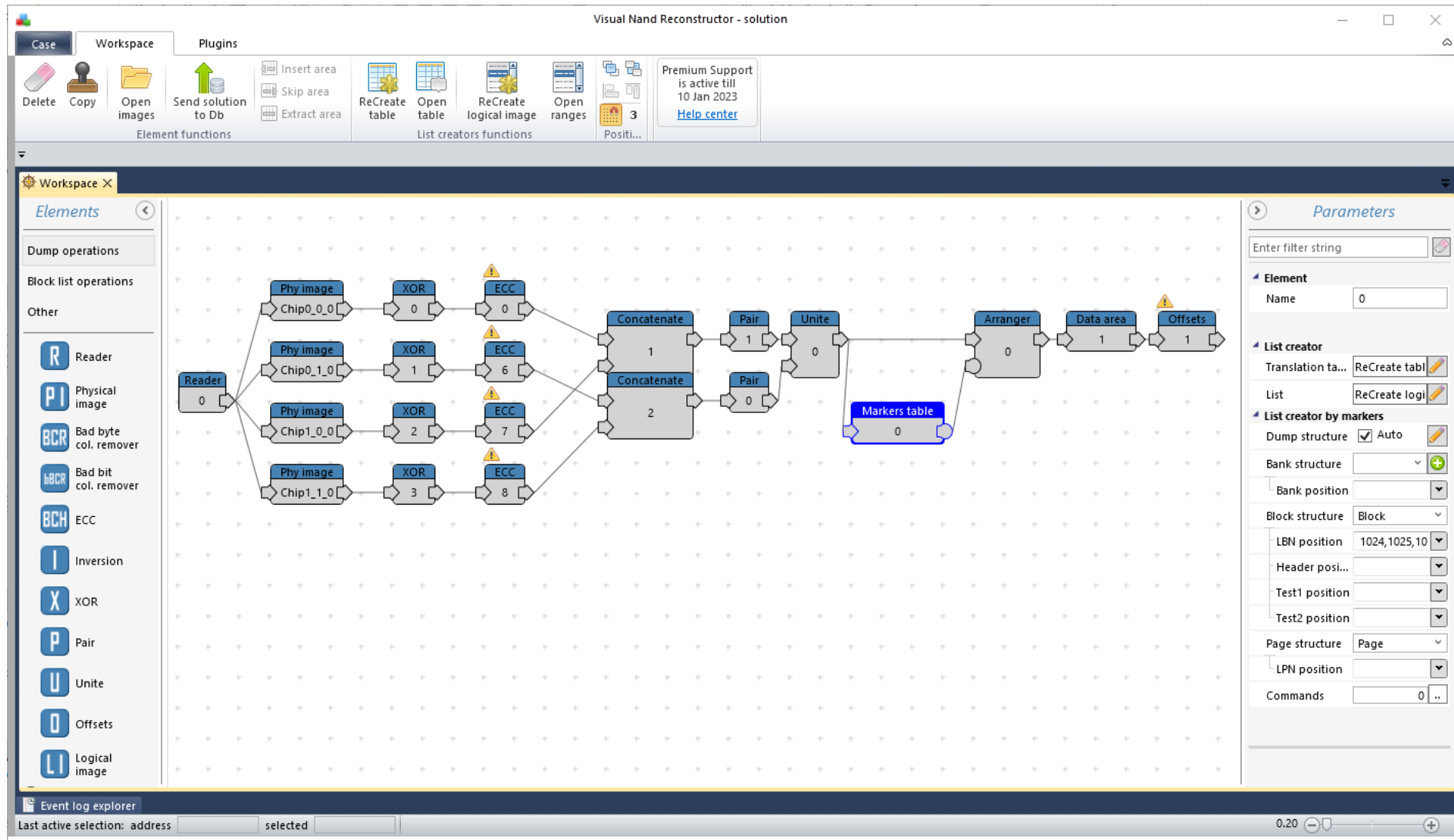
Physical image extraction from NAND



Do zrobienia jak i przetwarzania obrazu pamięci/(zrzutu, dump'a) zostało wykorzystane oprogramowanie Visual NAND Reconstructor.

Łącznie zostały zrobione 4 zrzuty, po jednym na płaszczyznę/kryształ

Rekonstrukcja obrazu - Emulacja kontrolera



Obrazy fizyczne są konwertowane do obrazu logicznego poprzez szereg operacji emulujących pracę kontrolera

Algorytm korekcji ECC został znaleziony – błędy bitowe zostały usunięte

The screenshot displays the Visual NAND Reconstructor software interface. The main workspace shows a workflow diagram with the following steps:

- Reader (0) feeds into four parallel paths.
- Each path contains a 'Phy image' block followed by an 'XOR' block (labeled 0, 1, 2, 3).
- The XOR outputs feed into four 'ECC' blocks (labeled 0, 6, 7, 8).
- The ECC blocks feed into two 'Concatenate' blocks (labeled 1 and 2).
- The concatenated outputs feed into two 'Pair' blocks (labeled 1 and 0).

The 'Parameters' panel on the right is configured as follows:

- Power: Off
- ECC codewords: JMicron(JM)UMF668_8832(ecc70b)_8.bch
- Page size: 9216
- Use buffer:
- Bytes rotate:
- ECC map:

The ECC map grid shows a 32x32 grid of green cells, indicating that all errors were correctable. A legend below the grid defines the colors:

- no errors (green)
- correctable errors (light green)
- not correctable er... (red)
- empty (grey)

The bottom status bar shows 'Last active selection: address selected' and a progress indicator at 0.20.

Translacja bloków – tworzenie obrazu logicznego

The screenshot displays the Visual NAND Reconstructor software interface. The main window is titled "Visual NAND Reconstructor - solution". The interface is divided into several sections:

- Case:** Contains icons for Markers edit, Block filter, and Block sorter.
- Markers table:** A toolbar with icons for LBN step (1/1), Find repeat (LBN), Move to (0), Sync with dump, and Reread selected blocks by ECC.
- Workspace:** The main area is split into two panes:
 - Block markers:** A table listing blocks with columns: Use, Bank, LBN, Address, PBN, LB, RB. The row with LBN 006D00 and Address 035B800000 is selected.
 - Page markers:** A table listing pages with columns: LPN, Address. The first row (LPN 00000000, Address 035B800000) is selected.
- Bottom status bar:** Shows "Position 0x7B from 0x103B" and "Position 0x0 from 0x3FF".

Kolejność bloków została ustalona na podstawie logicznego numeru bloku (LBN – logical block number)

Zrekonstruowany system plików za pomocą VNR

The screenshot displays the Visual Nand Reconstructor (VNR) application window. The title bar reads "Visual Nand Reconstructor - solution". The interface includes a menu bar with "Case" and "File system viewer". Below the menu is a toolbar with various icons for file system operations: Check headers, Save image, Save selected, Check file system, Create unallocated data dump, Correct allocated, Correct unallocated (ECC), Correct selected files data, Android data extractor, SQLite carver, and Refresh.

The main workspace shows a file system view for "Volume0 (Microsoft NTFS) SSDv9 29.82 GB". The left pane shows a tree view with "Root" selected. The right pane displays a list of files and folders with columns for Name, Ext, Size, and Last modified. The files listed include:

Name	Ext	Size	Last modified
R251-275			06/07/2022 16:07:37
R276-300			06/07/2022 16:07:37
R301-325			06/07/2022 16:07:37
R326-350			06/07/2022 16:07:37
R351-375			06/07/2022 16:07:37
System Volume Information			06/07/2022 16:07:15
SAttrDef		2.50 KB	06/07/2022 16:07:13
SBadClus		29.82 GB	06/07/2022 16:07:13
SBitmap		954.09 KB	06/07/2022 16:07:13
SBoot		8.00 KB	06/07/2022 16:07:13
SLogFile		41.67 MB	06/07/2022 16:07:13
SMFT		256.00 KB	06/07/2022 16:07:13
SMFTMirr		4.00 KB	06/07/2022 16:07:13
SSecure		257.84 KB	06/07/2022 16:07:13
SUpCase		32 bytes	06/07/2022 16:07:13
SVolume		0 bytes	06/07/2022 16:07:13
autorun	ico	152.55 KB	01/07/2022 09:47:16
AUTORUN	INF	44 bytes	01/07/2022 09:47:34
EVENTLOG	TXT	128.00 KB	01/07/2022 09:47:14
mfc100	dll	4.19 MB	01/07/2022 09:47:20
msvcr100	dll	755.83 KB	01/07/2022 09:47:08
NTFS	EXE	952.50 KB	01/07/2022 09:47:28
xFULL-F	txt	256 bytes	06/07/2022 16:07:33
xQUICK-F	txt	256 bytes	06/07/2022 16:07:36

At the bottom of the window, there is an "Event log explorer" tab and a status bar showing "Last active selection: address selected".

System plików został zrekonstruowany pomyślnie dla tego dysku SSD, a znaleziony algorytm rozwiązania powinien działać na wszystkich urządzeniach z identyczną pojemnością mających przy tym ten sam kontroler i Identyfikator NAND .

Wnioski(podsumowanie):

Pamięć SLC jest najbardziej niezawodnym rodzajem pamięci NAND.

Nawet biorąc pod uwagę krytyczne scenariusze takie jak uszkodzenie termiczne, nadal istnieje duże prawdopodobieństwo odzyskania danych.

Dopóki pamięć nie jest uszkodzona fizycznie, złamana, rejestrator lotu powinien być w stanie zachować dane.

Algorytm używany poprzez kontroler do zapisu danych w pamięci NAND, został oddany inżynierii wstecznej i w pełni zrekonstruowano obraz logiczny, który z kolei może być analizowany poprzez oprogramowanie producenta w celu uzyskania wymaganych danych.

Most of the black box pictures and testing materials were kindly provided by Etep
www.etep.com

Dziękuję za uwagę



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