Miniaturization of Metallized Polyester Film Capacitors

Tchavdar Doytchinov

EXXELIA GROUP

Exxelia Technologies

Film Capacitors BU

Space Passive Component Days
2nd International Symposium
ESA/ESTEC 12-14 October 2016

EXXELIA TECHNOLOGIES FILM CAPACITORS

GOAL OF THE PROJECT:

- ESCC EVALUATION & QUALIFICATION OF NEW SERIES IN PET TECHNOLOGY
- BUT NOT ONLY …

THANKS TO THE CONTRIBUTION OF:

DENIS LACOMBE (ESA), JEAN-PAUL BUSSENOT (CNES), LÉO FARHAT (ESA), LIONEL BONORA (ESA), OLIVIER PERAT (ESA)

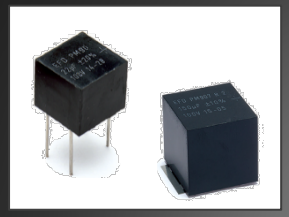
EXXELIA FILM CAPACITORS FOR SPACE

EXXELIA TECHNOLOGIES
FILM CAPACITORS

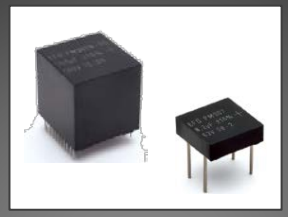
- 100% MULTISTEP CONTROL PRODUCTION PROCESS
- 100% END PRODUCTION TESTS AND RESULT ANALYSIS
- LOT ACCEPTANCE TESTS ACCORDING ESA REQUIREMENTS (ON REQUEST)

30 years of Experience in SPACE with **Catalog** products & **Custom designs** Numerous **unique ESA qualifications**

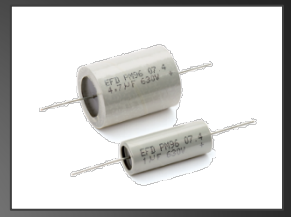
HIGH CAPACITANCE



PM 90 S

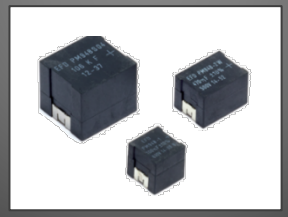


PM 907 S

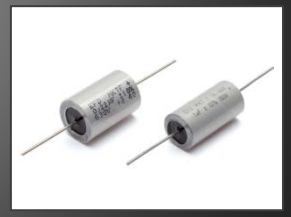


PM 96 S (T)

PM 94 S



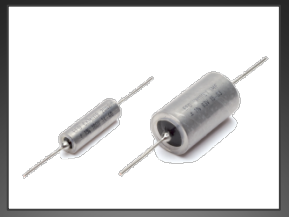
PM 948 S



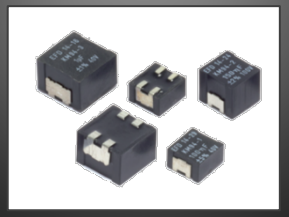
MKT S

METALLIZED POLYESTER
According to ESA-SCC 3006/019, 020, 024…

PRECISION



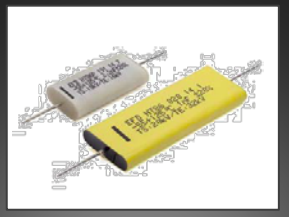
KM 111 TS



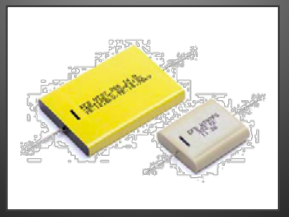
KM 94 S

PC ESA-SCC 3006/007
PPS ESA-SCC 3006/023

HIGH VOLTAGE



HT 86P S



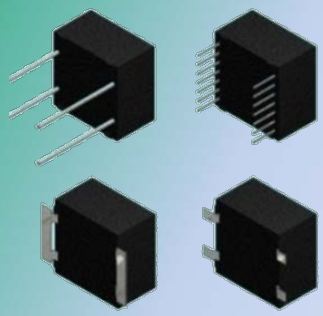
HT 97P S

RECONSTITUTED MICA
ESA-SCC 3006/018, 022

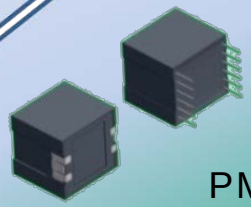
EXXELIA TECHNOLOGIES FILM CAPACITORS

PET AS ALTERNATIVE FOR DC FILTERING AND ENERGY STORAGE

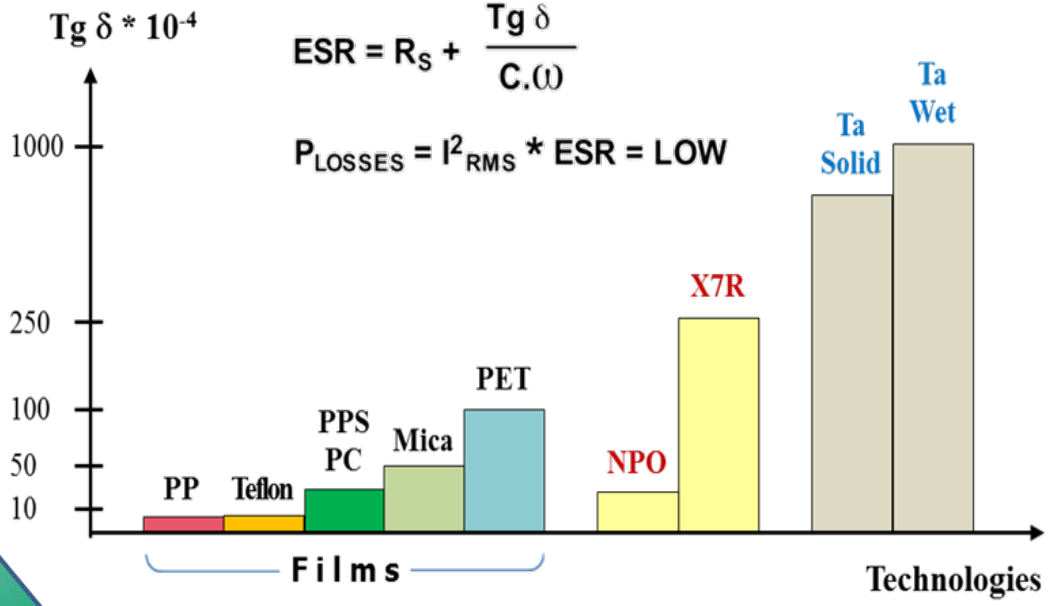
- HIGH RELIABILITY AND OPEN CIRCUIT FAILURE MODE (NO PROTECTION REQUIRED)
- STABLE ELECTRICAL CHARACTERISTICS (NO CAPACITANCE DRIFT UNDER VOLTAGE)
- BETTER POWER BEHAVIORS (EVEN LOWER ENERGY DENSITY)
- LOWER MASSE (UP TO 4-6 TIMES)
- THERMOMECHANICAL WITHSTANDING (FLEXIBLE STRUCTURE)



PM 907 S SERIES



PM 948 S SERIES



EXXELIA TECHNOLOGIES FILM CAPACITORS

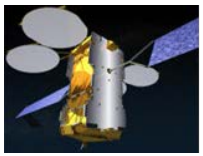
T° RANGE -55°C / +125°C

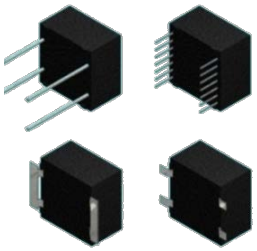
CONTINUOUS DESIGN IMPROVEMENT FOR BETTER MINIATURIZATION & INTEGRATION BEHAVIOR

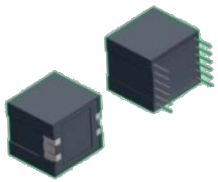
1990	1994	2007	2008	2008 - 2009	2009 - 2012	2013 - 2016
DEVELOPMENT OF **PM90 & PM94** ESA EVAL-QUALIF		**NEW SERIES PM907 & M948 MINIATURIZATION**		**EUROFARAD** INTERNAL QUALIF PM907 & PM948	**CNES** ESCC EVAL PM907S & PM948S	**ESA** EVAL & QUALIF PM907S & PM948S

TYPICAL CHARACTERISTICS

- SELF-HEALING PROPERTIES
- OPEN CIRCUIT FAILURE MODE
- HIGH RELIABILITY & QUALITY
- HIGH ENERGY DENSITY
- VERY LIGHT MASSE
- LOW ESR & ESL







SMD SOLDERING QUALIFICATION IN SPACE, AERONAUTICS & DEFENSE:

- ESA QUALIFICATION 500 T° CYCLES
- AIRBUS QUALIFICATION 1000 T° CYCLES

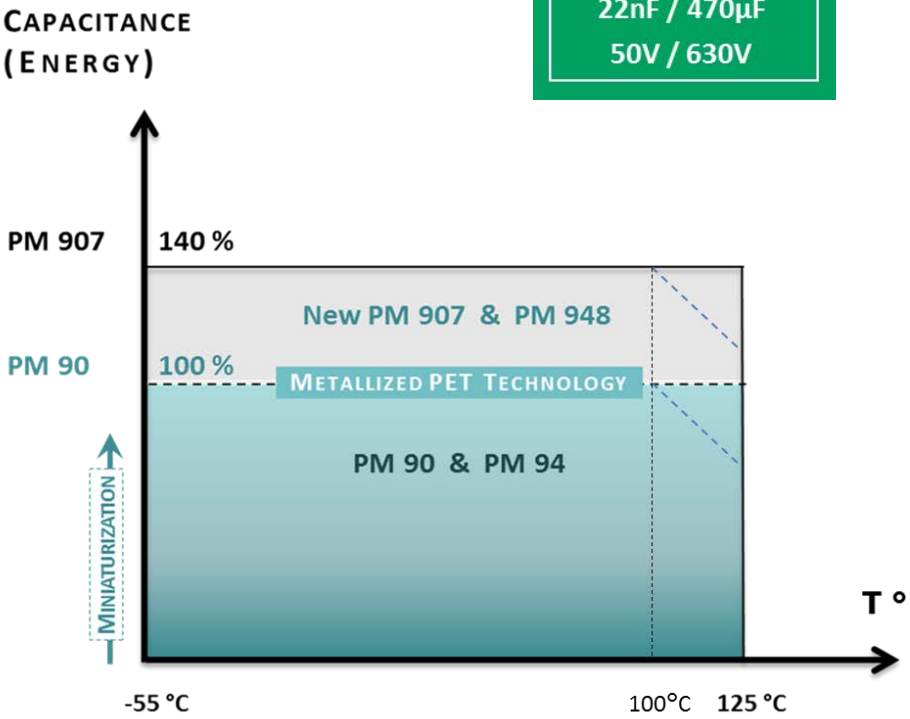
EXXELIA TECHNOLOGIES
FILM CAPACITORS

PM907 & PM948 DEVELOPMENT

1. **Development of PM907 & PM948**
   Based on well-known PM90 & PM94 -> 2007/2008
2. **In-House Qualification**
   According to ESA-ESCC and Others -> 2008/2009

ESA & CNES PROJECTS

1. **Technical Survey & Critical Requirements Review**
   (Design and Process trade off, PDR, FMEA-FTA, ...)
2. **Evaluation Testing and Analysis**
   ETP, Failure & Reliability Analysis, CDR,
   Soldering Process Evaluation with 500 cycles
   According to ESCC and ECSS standards
   5 years Testing
3. **Qualification Testing and Analysis**
   QPL, Final PID & Detail Specification, Test Analysis
4. **Final Review and Technical Data Package**
   (> 20 documents)



EXXELIA TECHNOLOGIES FILM CAPACITORS

ESA & CNES EVALUATION TESTS

ACCORDING TO ESA-ESCC-2263000 AND ESA-ESCC-3006

SEVERAL MILLIONS OF COMPONENTS-HOURS TESTS UNDER DIFFERENT ACCELERATED CONDITIONS

INCOMING CONTROL : DIMENSIONS, ASPECT, MARKING, ELECTRICAL CONTROL, X-RAY, etc.

Group 1

CONTROL GROUP

Group 2

DESTRUCTIVE TESTS

SUBGROUP 2A

THERMAL SHOCK
-55°C/+125°C

CONSTRUCTION ANALYSIS

DPA

SUBGROUP 2B

VOLTAGE STEP-STRESS AT T° MAX = +125°C

T° STEP-STRESS UNDER U_R

FAILURE MODE ANALYSIS

SUBGROUP 2C

MECHANICAL CAPABILITY

ACCELERATED DAMP HEAT TEST

ROBUSTNESS TERMINATIONS

SOLDERABILITY TEST

Group 3

STEADY-STATE ACCELERATED LIFE TESTS

U & T°	100°C	125°C	130°C
1,0 U_{RC}		X / X	X
1,2 U_{RC}	X	X	
1,25 U_{RC}	X	X	
1,4 U_{RC}	X	X	

ADDITIONAL TESTS AND INVESTIGATIONS:

- SOLDERING PROCESS BEHAVIORS
- SELF-HEALING VERSUS MAXIMUM ENERGY ASSEMBLY

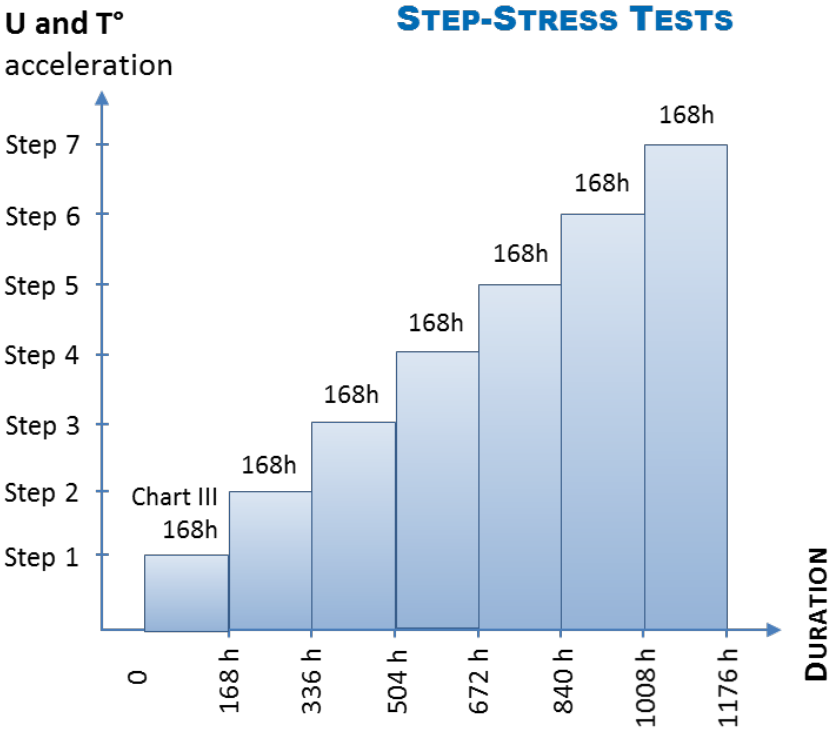
EXXELIA TECHNOLOGIES FILM CAPACITORS

ESA & CNES Evaluation Tests

More than 5-6 Years Testing

In the frame of ESA & CNES Contracts

Step-Stress Tests



Voltage Step-Stress

$U_{n+1} = U_n + 0{,}2 \cdot U_{RC}$

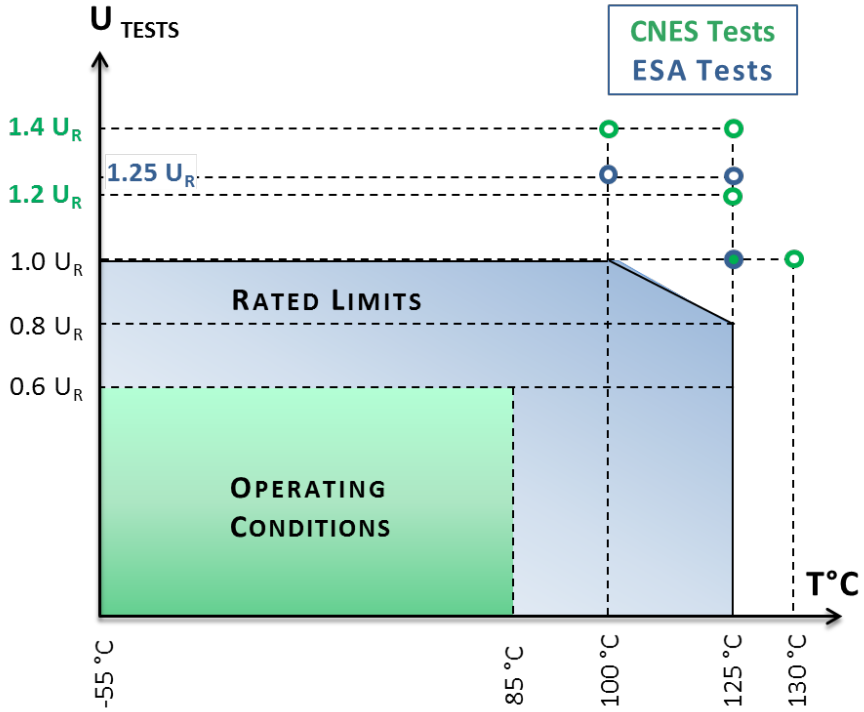
up to 1.8 / 2.2 U_R

Temperature Step-Stress

$T_{n+1} = T_n + 5°C$

up to 135°C / 150°C

Steady-State Accelerated Life Tests



Failure Mode Analysis

Open Circuit Failure Mode
in Rated Safety Zone
Thanks to Excellent Self-Healing

EXXELIA TECHNOLOGIES FILM CAPACITORS

Reliability Analysis

Aging Model Analysis & Comparison

Arrhenius Law :

$$\frac{t_1}{t_2} = \left(\frac{V_2}{V_1}\right)^n e^{\frac{E_a}{k_B}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$$

n = Voltage Acceleration Factor
Ea = Activation Energy [eV]

Acceleration Factors For Metallized PET

MIL-HDBK-217 : widely used for Reliability Calculation, but based on very Old Technological Data

MIL HDBK 217	Ea = 0,15 eV	n = 5	→ No Specific Treatment of the Dielectric -> Very Low Ea Very Low Electrical Stress on the Film -> Very Low n
ASTRIUM	Ea = 0,85 eV	n = 6	→ Data based on PM90S / PM94S series Some Specific Treatment on the Dielectric
Eurofarad	Ea = 0,8 eV	n = 7	→ Experimental Data of PM907S / PM948S High Electrical Stress & Specific Treatment

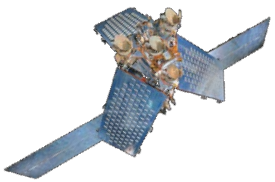
No Need of Very Accelerated Tests

Qualification Test
2000h U_R at 125°C

Max Operating Conditions
0.6U_R & 85°C

→

Acceleration Factors	Astrium	Eurofarad
Ea (T°)	0,85 eV	0,8 eV
n (U)	6	7
Equivalent Life Time	~ 700 000 h	**~ 1 000 000 h**



EXXELIA TECHNOLOGIES FILM CAPACITORS

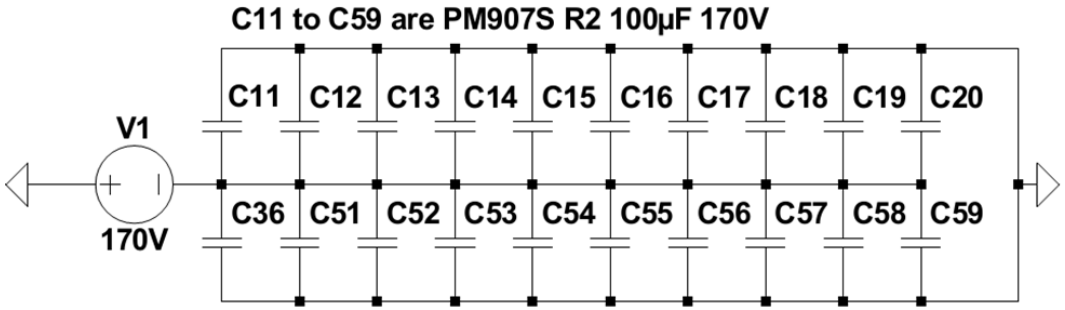
SELF-HEALING PROPERTIES AND ENERGY LIMIT ACCORDING TO PREVIOUS ECSS-Q-ST-30-11C

GOAL **ECSS-Q-ST-30-11C**

Demonstrate Self-Healing Behaviour

with 2 x Energy (previous ESA limit 15 Joules)

CAPACITOR BANK OF 30 JOULES ENERGY WITH PM907S 100µF 170V



TEST

Capacitor bank Assembly
Done with PM907S 100µF 170V
(biggest capacitance proposed for 100Vdc BUS)

Capacitor Bank is directly connected to the Power Supply without any protection.

Test has been done at 125°C under 170Vdc combining voltage and temperature acceleration.

RESULTS

- First Step: OK after 2000h
- EOL drift of capacitance to OPEN CIRCUIT

EXXELIA TECHNOLOGIES FILM CAPACITORS

SOLDERING PROCESS TESTS

PM94S HERITAGE:

SMD CAPS SOLDERED ON PCB AND TESTED WITH -55°C/+125°C CYCLES

- EUROFARAD (MBDA) QUALIFICATION 1000 T° CYCLES 2006
- AIRBUS QUALIFICATION (AERONAUTICS) 1000 T° CYCLES 2006
- ESA QUALIFICATION (VOQ) WITH 500 T° CYCLES 2007

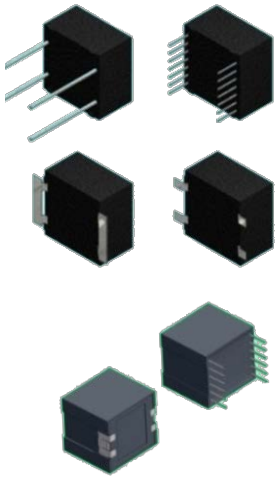


PM907S & PM948S ESA & CNES EVALUATION:

- PM907NS (DIL VERSION) 500 T° CYCLES – ALREADY DONE 2010

  DESIGN OF REPRESENTATIVE PCB FOR SPACE USED BY THALES ALENIA SPACE
  SOLDERING OF THE CAPACITORS ON THE PCB BY THALES ALENIA SPACE
  TESTS WITH 500 T° CYCLES ACCORDING TO ECSS & ESCC STANDARDS

- PM907S (R1, R2 TYPE SMD VERSIONS) 500 T° CYCLES 2016
- PM948S (SMD VERSION) WITH 500 T° CYCLES 2016



Exxelia Technologies Film Capacitors

Examples of Polyester Capacitors In Space Applications

- Power Conditioning Units (PCU)
- Power Control & Distribution Units (PCDU)
- Battery Charge and Discharge Regulators
- Bus Filter Capacitor Module
- Array Power Regulators
- Power Regulators for Antennas Position

- Power Processing Units
- Modular DC/DC converters
- Motor control electronics for mechanism drives
- Electrical Propulsion Thrusters (Ion, Plasma, Hall Effect, FEEP ...)
- Etc.

EXAMPLE OF PROJECTS FOR SPACE

EXXELIA TECHNOLOGIES
FILM CAPACITORS

30 years of Experience in SPACE with **Catalog** products &
Custom designs Numerous **unique ESA qualifications**

A5B	CASSINI	GOCE	LOCSTAR	OBZOR	SICRAL
AGE	CESASAT	HELIOS	LUCH	PLANCK	SILEX
AGSTENTOR	CLUSTER	HERSCHEL	MAB	PMT	SOLAR Orbiter
ALOS 2	COMSAT	HISPASAT (G)	MARS Express	POSEIDON	SPACELAB
ALPHABUS	EMS	HOTBIRD 4	MARS Insight	PPF	SPOT (4&5)
AR2	EMS2	HTV	MASAS	PROTEUS	STENTOR
ARABSAT (G)	ENVISAT1	HUYGENS	MELFI	PTG	TDE
ARKTIKA	EOSAT	INMAR-TLC2	METEOR	Quantum	TDF (G)
ARGOS	ERS	INSAT	METEOSAT	RADARSAT	TELECOM2 (G)
ARIANE 4	EUCLID	INTELSAT (G)	METOP	RapidEye	TERRA-SAR
ARIANE 5	EUTELSAT (G)	INTEGRAL	MPLM	ROSETTA	THURAYA
ARIANE 6	EXOMARS	IRS	MSG	SANTINEL	TR6
ARTEMIS	FIRST	IRRIDIUM	MTSAT	SARah	TURKSAT (G)
ASTRA 1K	GALILEO	ISS	NAHUEL (G)	SARLUPE	VEGETATION
ASIASAT (G)	GLOBALSTAR	ITALSAT (G)	NEUROLAB	SARSAT	XMM
ASTRO 15	GLONASS	LISA Pathfinder	NILSAT (G)	SHB	XSAR
ATV					WORLDSTAR

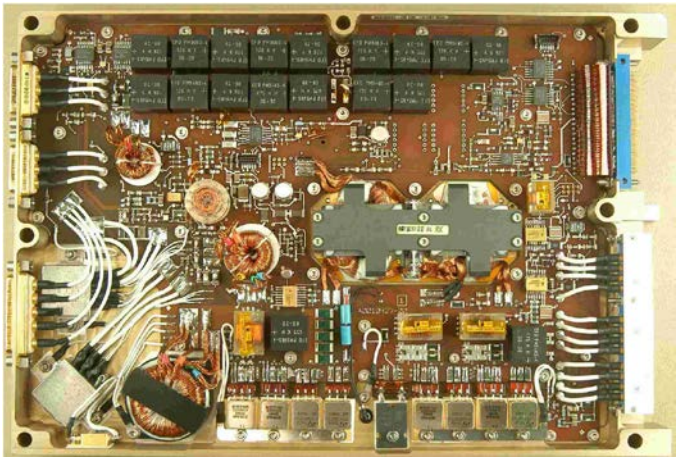
AND MANY OTHERS ...

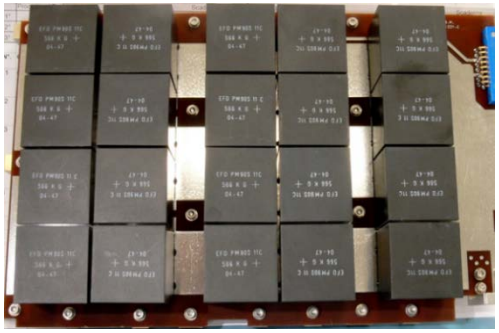
EXAMPLES : PET CAPACITORS FOR SPACE

STANDARD PM SERIES FOR SPACE APPLICATIONS

EXXELIA TECHNOLOGIES
FILM CAPACITORS

AIRBUS DS – BATTERY REGULATOR FOR ALPHABUS



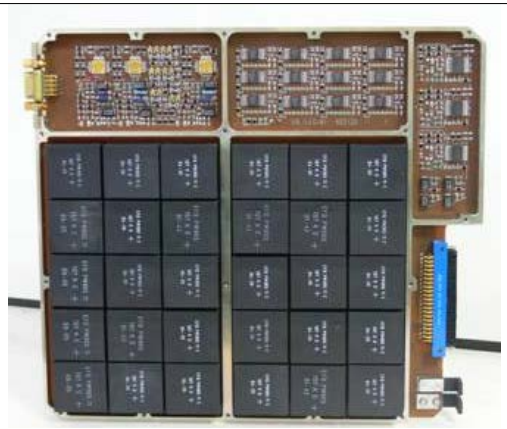


PCDU BUS FILTER
AIRBUS DS, TAS, SELEX ES

NASA & ESA DEVELOPMENT OF ATV AND ORION MPCV

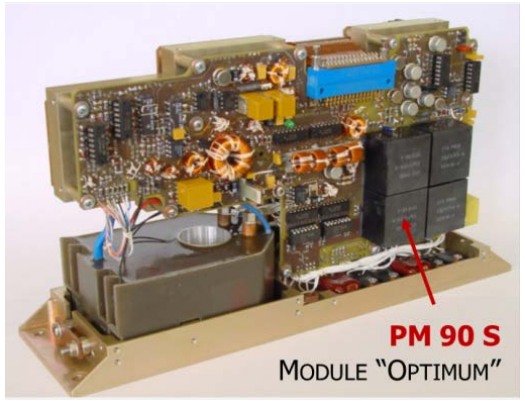
Selex ES
A Finmeccanica Company

BUS FILTER CAPACITOR MODULE
PCDU FOR GAIA PROJECT

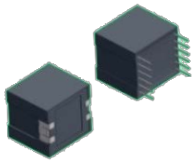


PM907S
&
PM948S

ASTRIUM PLASMA THRUSTER
EUROPEAN SPACE MISSION **GOCE**



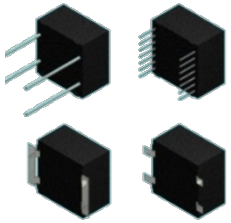
Electric Propulsion Applications (PPU)



NEW IN QPL

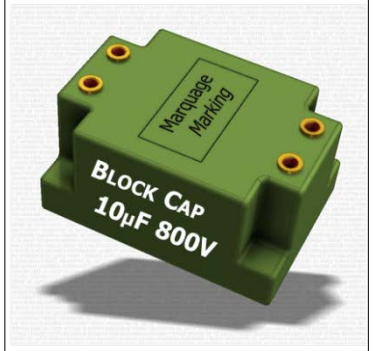
PM907S

PM948S

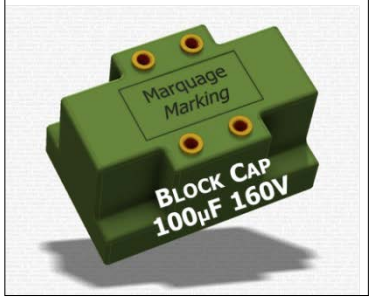


- THALES ALENIA SPACE
- AIRBUS DEFENSE & SPACE
- MITSUBISHI MELCO
- MBT - IAI GROUP
- POLUS
- ETC.

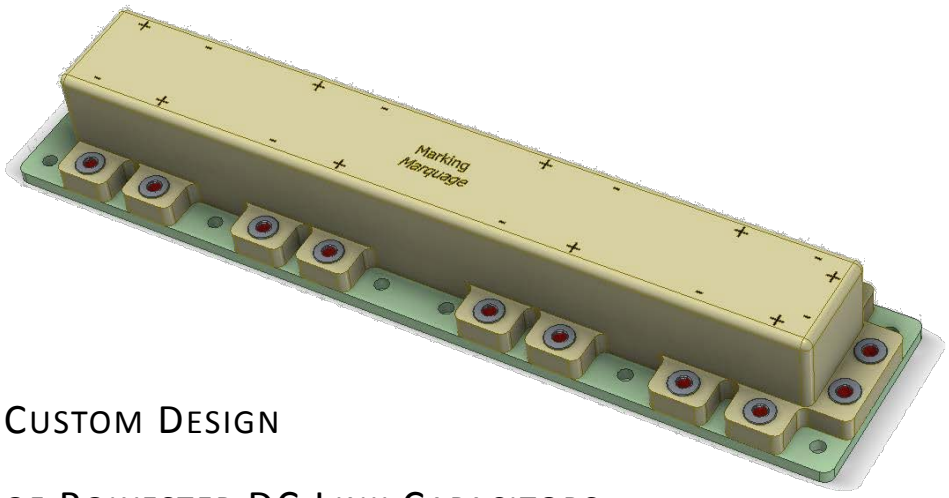
CUSTOM DESIGN
BASED ON PET TECHNOLOGY



HALL EFFECT THRUSTER
FOR PLATFORM **NEOSAT**



NEW ARIANE 6

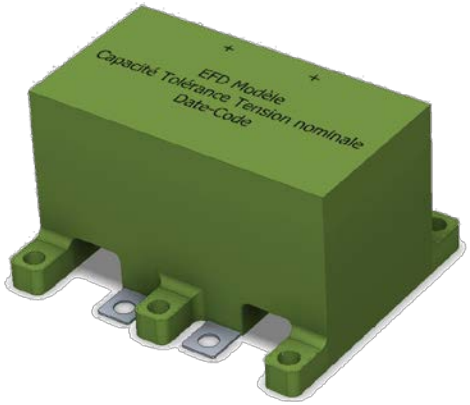


CUSTOM DESIGN

OF POLYESTER DC LINK CAPACITORS

NEW CUSTOM DESIGN FOR THALES

LAUNCHER VEGA NEW GENERATION



EUROFARAD CUSTOM DESIGN

NEW FILM TECHNOLOGY

NEW PROJECT WITH SABCA

PET Capacitors for Aero & Defense

EXXELIA TECHNOLOGIES
FILM CAPACITORS

APPLICATIONS :

- TRU (Transformer Rectifier Unit)
- Flight controls
- Electrical Thrust Reverser Actuator
- Electric Brake Actuation Controller
- Landing Gear
- Cabin Pressure Control Systems
- Air Conditioning Systems
- Actuator's Power Supplies
- Signalization
- etc.

DC Link Capacitors

AIRBUS, DASSAULT
BOEING, BOMBARDIER
SAAB, AVIC, SUKHOI, UTAS,
THALES, SAFRAN, LIBHERR,
HONEYWELL, MEGGITT,
GE Aviation, UTC,
Etc.

Civil & Military Avionics

EXXELIA TECHNOLOGIES FILM CAPACITORS

EXAMPLE : EUROFARAD FILMS ON A380

- **COMPUTER AND DATA CONTROL**
  AIRBUS
- **TRU** (TRANSFORMER RECTIFIED UNIT)
  THALES
- **DOOR OPENING ACTUATOR**
  LIEBHERR
- **FLIGHT CONTROL**
  GOODRICH

- **SIGNALIZATION**
  ZODIAC
- **AIR CONDITIONING**
  LIEBHERR
- **EMA FOR LANDING GEAR**
  MESSIER-BUGATTI, SAGEM
- **BPS** (BACK-UP POWER SUPPLY)
  SAGEM
- **ETRAC**
  SAFRAN HISPANO-SUIZA
  ELECTRICAL THRUST REVERSER ACTUATION CONTROLLER

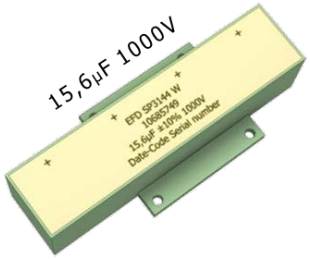
- **FADEC-3** (FULL AUTHORITY DIGITAL ENGINE CONTROL)
  (BUT ALSO A400M, DIFF BOEING, SUPERJET 100)
  SAGEM

EXAMPLE : EUROFARAD FILMS ON A350

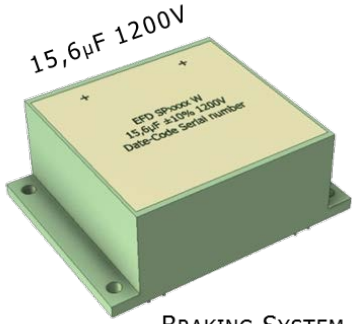
- **COMPUTER AND DATA CONTROL**
  AIRBUS

- **BRAKING SYSTEM ACTUATOR**
  LIEBHERR

- **EPCS** (ELECTRICAL POWER CONVERSION SYSTEM)
  THALES

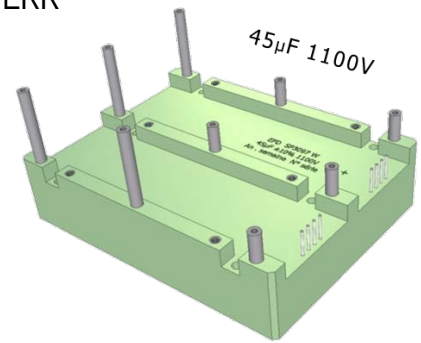


EUROFARAD CUSTOM DESIGN
& STANDARD PARTS SOLUTIONS

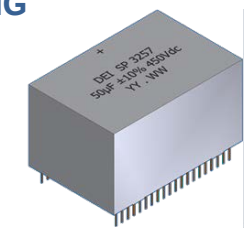


BRAKING SYSTEM

- **FLIGHT CONTROL**
  FLAP & SLAT SYSTEMS
  LIEBHERR



- **AIR CONDITIONING**
  HONEYWELL



A S C U
(AIR SYSTEM CONTROL UNIT)

- **FADEC**
  (FULL AUTHORITY DIGITAL ENGINE CONTROL)
  FOR ROLLS ROYCE AND GENX ENGINES
  SAGEM

EXXELIA TECHNOLOGIES
FILM CAPACITORS

THANK YOU