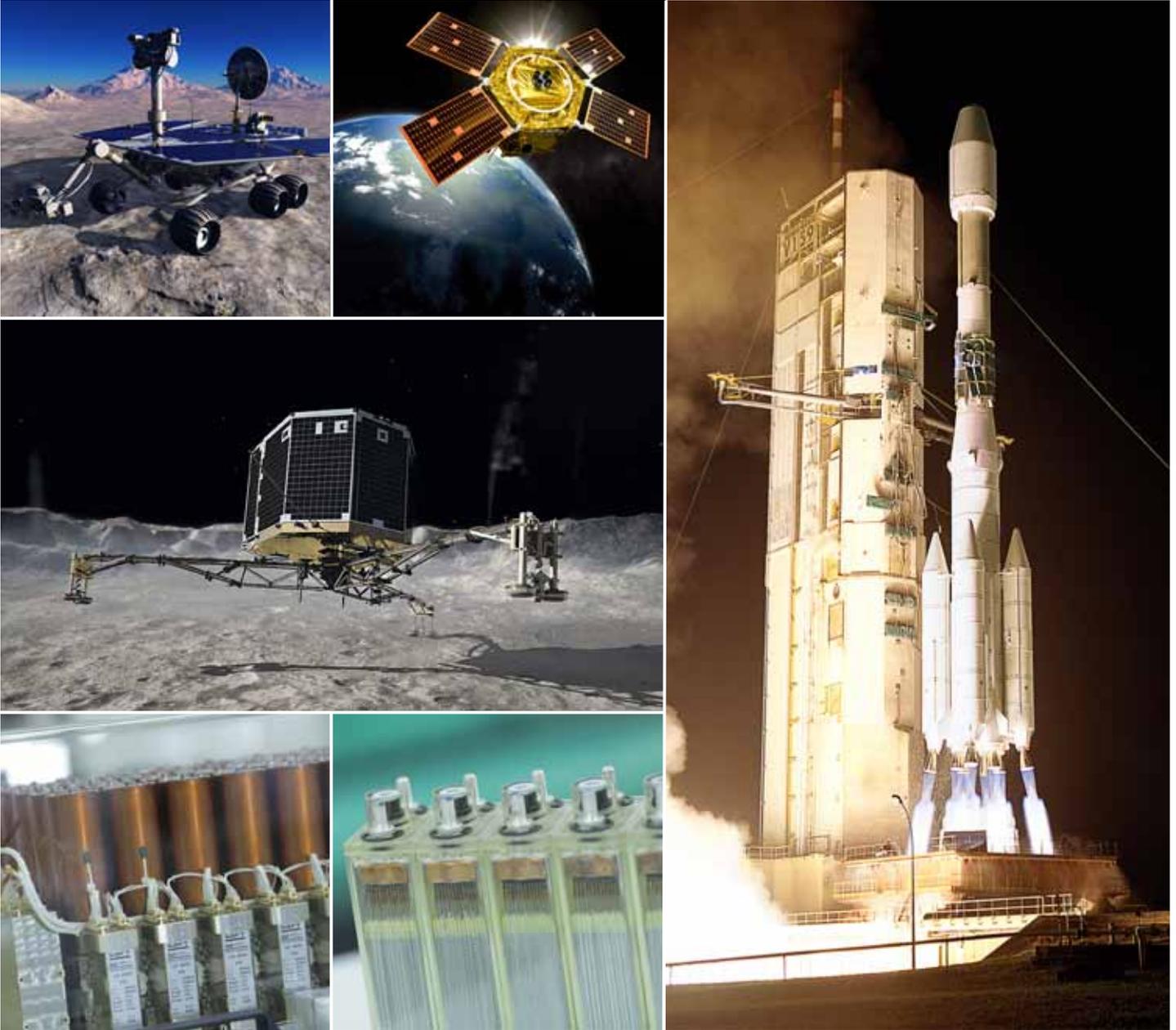


# Saft batteries... powering outer space for 50 years

Extreme performance batteries meeting the demands of space applications



**SAFT**

# Saft, a pioneer in space...



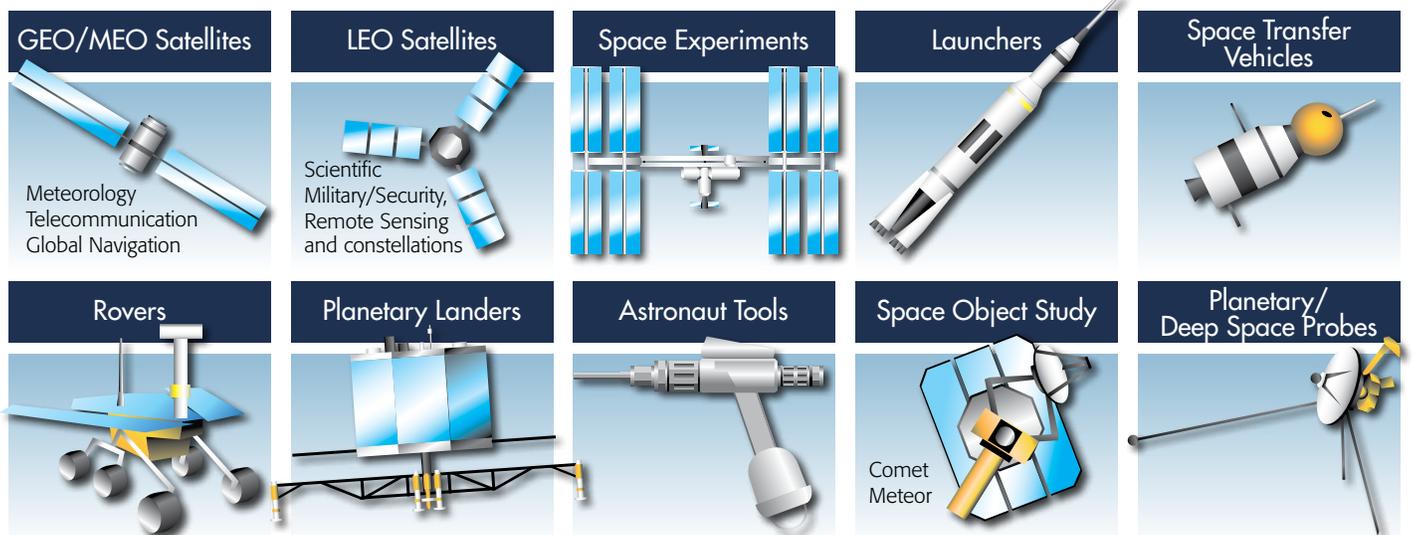
Saft is the world leader in developing and manufacturing batteries for the space market. With more than 50 years of experience, Saft has become a pioneer in space through innovative thinking and development of advanced technology. Since the launch of our first battery in 1966 on board the D1A "Diapason", Saft has gained significant experience to become the top supplier worldwide of batteries for satellites and a multitude of space applications.

## Superior technology

Saft's global customers include prime contractors, telecoms operators and space agencies. These organizations value our complete mastery of all battery chemistries, whether primary or rechargeable. They also value our proven ability to develop new products and offer breakthrough technology. Saft is the only battery manufacturer offering all technologies used in space: nickel (Ni-Cd, Ni-H<sub>2</sub>), primary lithium (Li-SO<sub>2</sub>, Li-SOCl<sub>2</sub>, and Li-MnO<sub>2</sub>), and rechargeable lithium (Li-ion), preparing the future with new non-rechargeable and rechargeable technologies.

## Space applications served by Saft batteries

Low mass and volume coupled with long life and simplified electronics make Saft's highly customizable battery solutions perfect for these applications:





## Unrivalled space flight heritage



## Saft has...

- Supplied nearly 35,000 cells for space flight
- Orbited on 768 satellites launched on 325 launchers
- Had over 170 successful launches with Li-ion batteries, showing very high reliability
- Put in orbit more than 2 million Wh Li-ion batteries
- More than 350 Li-ion batteries in orbit showing remarkable performance
- Supported GEO missions beyond 22.5 years with Ni-Cd and 18 years with Li-ion
- Supported LEO missions beyond 21 years with Ni-Cd
- Qualified their battery for the full electric GEO communication satellite requirements

## Proven in space, trusted universally

Saft encourages the active involvement of our customers by offering:

- Access to manufacturing lines
- Pro-activity in battery choice
- Clear visibility of products and road maps
- Cooperation on research programs
- A track record of applications-led solutions for multiple industries

# Multiple technologies for demanding applications



While Li-ion technology has become the premier choice for satellites, Saft also offers its proven primary lithium technology for probes, rovers and other space vehicles. These applications need long-lasting power that operates in extreme temperatures while powering crucial flight operations for these one-off missions.

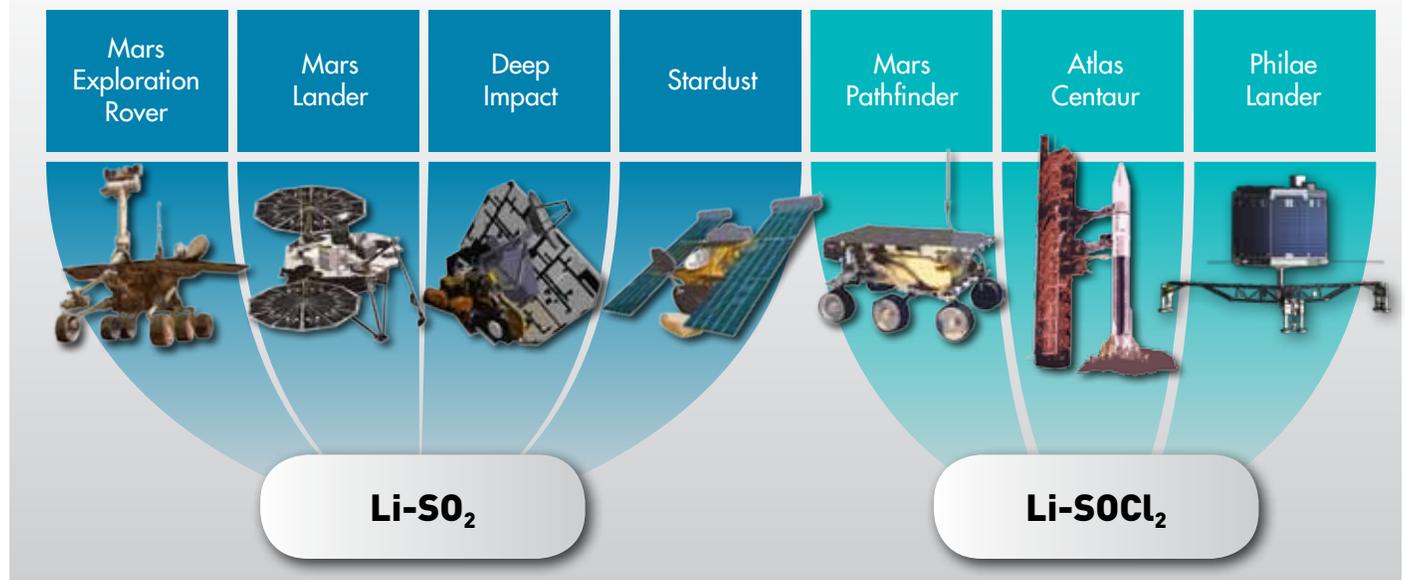
## Built to meet objectives

Saft's Li-ion cells are specially adapted for space applications from field-proven designs. Cells are manufactured at three sites – Cockeysville, MD (USA), Poitiers (France), and Bordeaux (France) – which together meet the demanding quality, schedule and cost objectives of space programs.

In 2014, the great success of the Philae mission was directly linked

to the performances of the primary Li-SOCl<sub>2</sub> battery. After more than 10 years of travel in very cold conditions (less than -60°C), the battery has powered the probe onto the Tchouriomov-Gerasimenko comet allowing it to conduct more than 90% of the experiments planned and to ensure the telecommunication with Rosetta and Earth during the 3 first days on the comet.

## Proven primary lithium technology for specialized missions





## Saft's space-qualified Li-ion cell offering



	VES 140	VES 180	VL 48E	VL51ES	VES 16	VL 6P
Guaranteed capacity (Ah)	39	50	48	51	4.5	6.6
Mean voltage at C/1.5	3.6	3.6	3.6	3.6	3.6	3.6
End of charge voltage (V)	4.1	4.1	4.1	4.1	4.1	4.1
Energy (Wh)	140	180	170	180	16	22
Specific energy (Wh/kg)	126	165	150	170	155	65
Height (mm)	250	250	250	222	60	143
Diameter (mm)	53	53	54	54	33	38.2
Weight (kg)	1.13	1.11	1.13	1.08	0.155	0.34
Power capability current pulses A						225
Main application	GEO, MEO	GEO, MEO	GEO, LEO	GEO, MEO, LEO	LEO, GEO	Launcher

## Our customers in the space industry include:

- ARSAT
- Boeing
- CNES
- EADS Astrium
- ELV
- ESA
- IAI
- INTA
- INVAP
- ISRO
- KARI
- Lockheed Martin
- NASA
- Northrop Grumman
- OAO ISS Reshetnev
- OHB CGS
- Orbital Sciences Corporation
- Thales Alenia Space
- Energya
- SABCA
- Satrecl
- SSTL
- Tübitak Uzay
- VNIIEM
- Yuzhnoe Design Office

# Modular flexibility for optimized configurations



Saft's modular batteries are based on parallel and series assemblies, where a multitude of arrangements is possible from up to 12 cells in parallel with VES 180, VL 48E, and VL 51ES. (480 Ah) and up to 24 cells in series (100 V). These designs are available for GEO and MEO platforms ranging from 3 kW to 25 kW.

## The Saft concept: modular scalable battery systems.

Using Saft's manufacturing process, cells built on large, cost-efficient manufacturing lines are configured to meet precise market requirements. The cell modularity is realized for both parallel and serial assemblies.

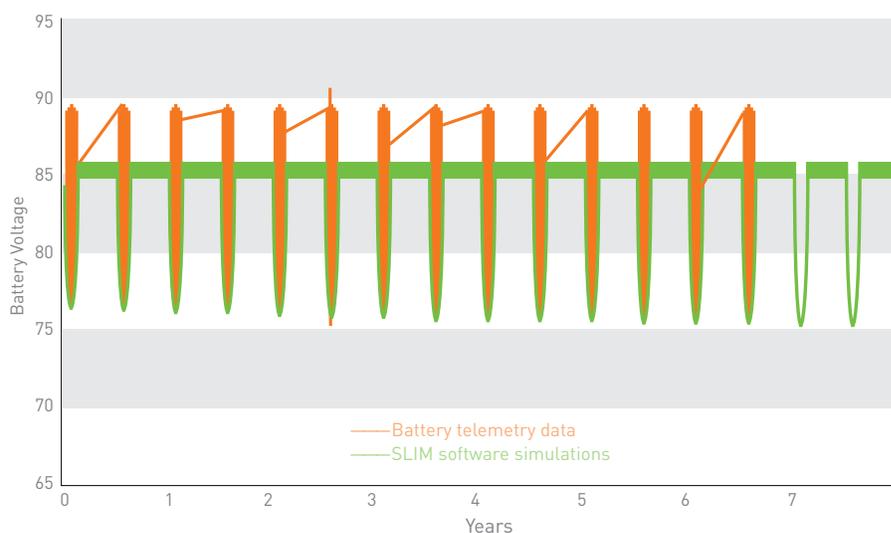
Cells are mechanically and electrically assembled into modules or customized battery systems, including electronic devices to govern performance, thermal and safety management.

## Saft Li-ion Model (SLIM)

Calculate optimum solutions, predict future performances. Saft uses its macroscopic electrochemical model, SLIM, in support of GEO, MEO and LEO satellite manufacturers to check the battery telemetry coming from operational satellite to evaluate the performances along the mission time. This information is used to find the best solutions through prediction of future VES battery performance.

The optimum configuration is found by inputting electrochemical characteristics - Energy, Capacity, Electro-Motrice Force (EMF), internal resistance and End of Charge voltage - or mission figures and profiles - power, duration, DoD, end of charge voltages, temperature during eclipse and solstice, and cell failures.

SLIM comparison vs. satellite telemetry data after 7 year mission duration



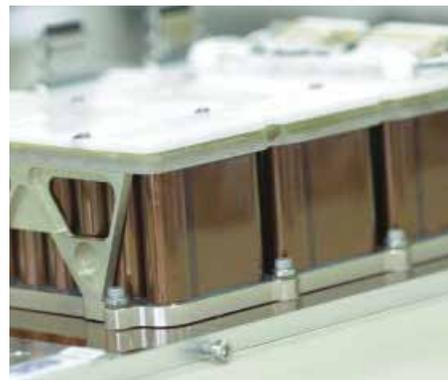


## Multiple s-p battery arrangement with VES16

The VES16 cell LEO performances are the best compared to all other cell designs thanks to its dedicated negative electrode. The electrode composition has been designed considering the LEO profile. Its large charge current capability provides a

very high efficiency with a large DOD (Depth of Discharge) >30 %. These batteries are dedicated to LEO observation, military or constellation satellites.

Moreover, the VES16 demonstrated very good stability in GEO missions. In 2015, TeLEOS 1 launch placed the first VES16 battery in orbit.



## Incorporating electronics for safety

Saft's fully integrated, "all-in-one" modular package combines electronics and electrochemistry to provide a system with intelligent autonomous cell balancing management, optimized for easy installation and instant operation.

The system function includes:

- Balancing – optimizes battery life and available energy
- By-pass – removes the weak or failed cells or modules from the serial circuit
- Disposal functions (discharge) – passivates battery modules at the end of the mission even after by-pass operated

Optimized for space cells VES 140 and VES 180 and suitable for battery configurations from 7s to 24s and 1p to 12p.

# Saft is committed to the highest standards of environmental stewardship

As part of its environmental commitment, Saft gives priority to recycled raw materials over virgin raw materials, reduces its plants' air and water releases year after year, minimizes water usage, reduces fossil energy consumption and associated CO2 emissions, and ensures that its customers have recycling solutions for their spent batteries.

Regarding industrial batteries, Saft has had partnerships for many years with collection companies in most EU countries, in North America and in other countries. This collection network receives and dispatches our customers' batteries at the end of their lives to fully approved recycling facilities, in compliance with the laws governing trans-boundary waste shipments.

Saft has selected a recycling process for industrial lithium-ion cells with very high recycling efficiency. A list of our current collection points is available on our web site. In other countries, Saft assists users of its batteries in finding environmentally sound recycling solutions. Please contact your sales representative for further information.



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