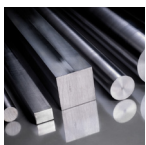


AUBERT&DUVAL



SPACE INDUSTRY METALLURGICAL SOLUTIONS



www.aubertduval.com

Equipment

Melting

Melting furnaces (EAF, AOD, VOD)
up to 60 tons
Vacuum Induction Melting (VIM)
up to 20 tons
Titanium Plasma Arc Melting
furnace (PAM-CHR)
Remelting furnaces (ESR, VAR)
up to 30 tons

Powder metallurgy

Gas atomization (VIM)

Forging

Open-die forging presses
from 1,200 to 10,000 tons
Closed-die forging presses
from 4,500 to 65,000 tons

Rolling mill

7-200 mm diameter bars

Heat treatment

Solution and ageing furnaces
Horizontal and vertical quenching
equipment

Testing

Immersion UT
up to 13 tons (28,000 lbs)
Automated contact UT
up to 20 tons

AUBERT & DUVAL

The Space industry supplier of choice

A&D has been selected on major space programs for its unique combination of metallurgical expertise and know-how along with world-class melting and forging tools. This unique industrial set-up enables us to offer highly reliable and secure metallurgical solutions for the most complex, lighter, large-scaled, critical and cryogenic applications.

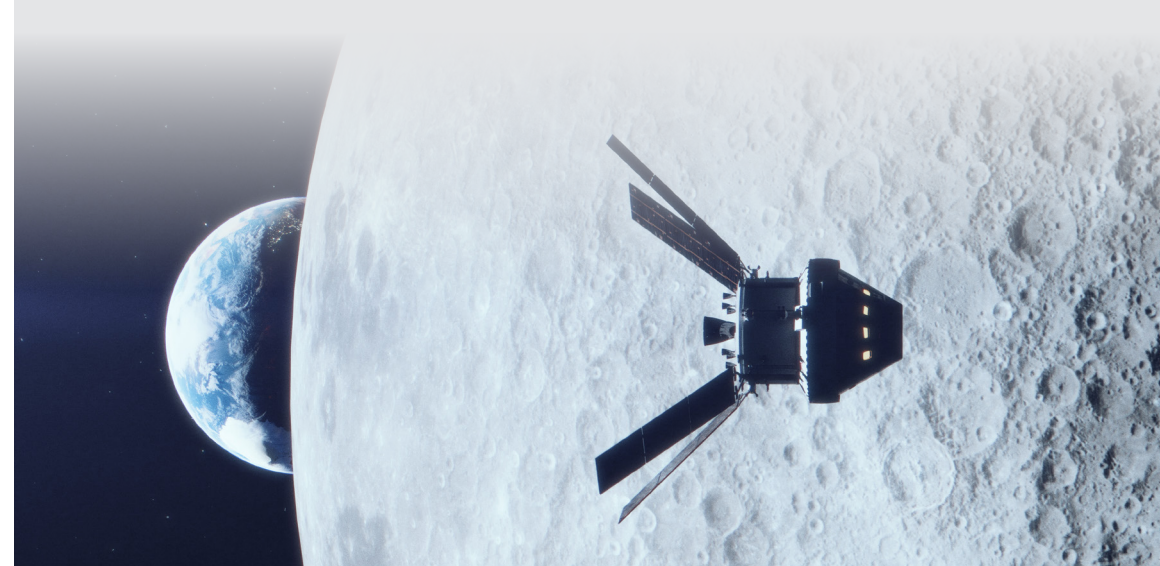
Thanks to this positioning, Aubert & Duval is supporting the development of the most ambitious projects: space stations, heavy or reusable launchers, spacecrafts as well as all satellite sizes.

A unique combination to help realize your ambitions

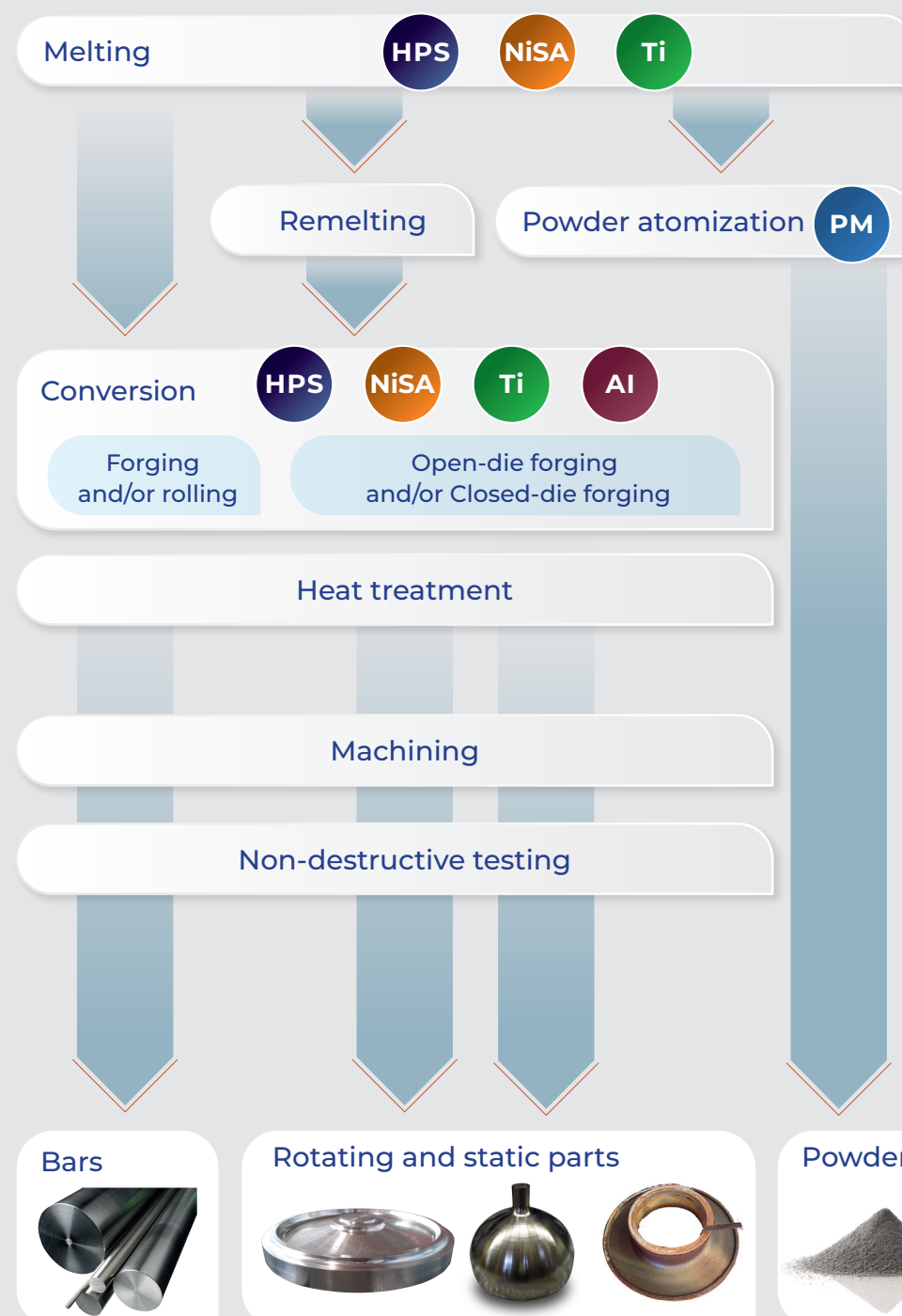
- Passionate teams driven by metallurgical innovation and industrial challenges.
- R&T and co-engineering culture with unrivalled simulation capabilities.
- A unique integrated solution of world-class tools from melting to closed-die forging.
- Multi-material expertise: special steels, superalloys, titanium, aluminum (forging only).
- A multi-certified player able to support customers' needs on all markets (aeronautics, defense, nuclear): ISO 9001/EN 9100, ISO14001, OHSAS 18001 ; NADCAP ; AQAP2110 ; TAA experienced (US market) , Fully Authorized Economic Operator (AEO).



The 65kt closed-die forging press: a world-class tool for the manufacturing of complex, large, thick and seamless parts



Process flow



Main materials

HPS High performance steels

A range of alloyed steels with tightly controlled characteristics, offering optimum value for customers.

NiSA Nickel-based superalloys

A range of alloyed materials with specific resistance to very high temperatures and corrosion, the majority component being nickel.

Ti Titanium alloys

Pure or alloyed titanium, combining mechanical properties and corrosion-resistance with light weight.

AI Aluminum alloys

Slightly alloyed aluminum, widely used in aircraft.

PM Metal powders

Steels, superalloys powders for additive manufacturing and aero rotating parts.

PARTS AND BARS

Main materials

AI

Aluminum alloys

▶ Al2000 series

▶ Al7000 series

▶ 5083

▶ 6061

▶ Aluminum-Lithium

Ti

Titanium alloys

AD grade

Common name

▶ TA6V

Ti6Al4V

▶ TA6V

Ti6Al4V ELI

▶ Ti10 2 3

Ti10 2 3

NiSA

Nickel-based superalloys

AD grade

Common name

▶ AD730®

NiCr16Co9Mo3W3Ti3Al2

▶ NY276

C276

NiMo16Cr15W

▶ PER3

Waspaloy

NiCr20Co13Mo4Ti3Al

▶ PER625

IN625

NiCr22M9Nb

▶ PER718

IN718

NiCr19Fe19Nb5Mo3

▶ XSH

KC20WN

CoCr20W15Ni

HPS

High performance steels

AD grade

Common name

▶ 819B

35NCD16

35NiCrMo16

▶ GKH®

32CDV13

32CrMoV12-9

▶ M50NiL

13MoCrNiV42-16-14

▶ Marval®18

M250

X2NiCoMo18-8-5

▶ ML340

X23NiCoCrMoAl13-6-3

▶ MLX®17

X1CrNiMoAlTi12-11-2

▶ MLX®19

X1CrNiMoAlTi12-10-2

▶ MO6ACW

D6AC

48CrMoNiV4-10

▶ SCV®

15CDV6

15CrMoV6

▶ X15U5W

15-5PH

X5CrNiCu15-5

▶ X18PA

X6CrNiTi18-0

▶ XD15NW®

X40CrMoVN16-2

▶ XDBD

440C

X105CrMo17

▶ XN26TW

A286

X6NiCrTiMoVB25-15-2

* Patented grade

AUBERT & DUVAL
Already
on board with

Launchers: Ariane, Vega ESA programs ; PSLV Indian program ;
Stations: ISS & Axiom programs ;
Spacecrafts: Orion & Cygnus programs ;
Satellites: very large range of programs from LEO to GEOSAT tanks ...

And you tomorrow!

AI FORGINGS

Ti FORGINGS

Propellant/
Helium Tanks



Spherical tanks
Up to 2 meters (79") diameter

HPS FORGINGS

NiSA FORGINGS

Propulsion Parts



1/2 shell manifold

Impeller

Shaft
Up to 4
meters (157")
long

AI FORGINGS

Ti FORGINGS

HPS FORGINGS

Structural Parts



Cone

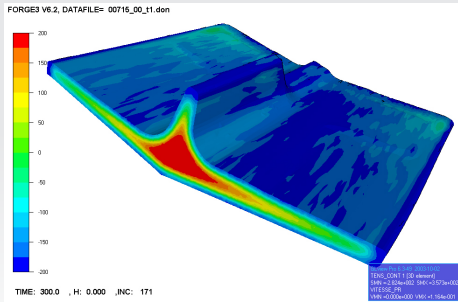
Dome

Bulkhead

Bracket

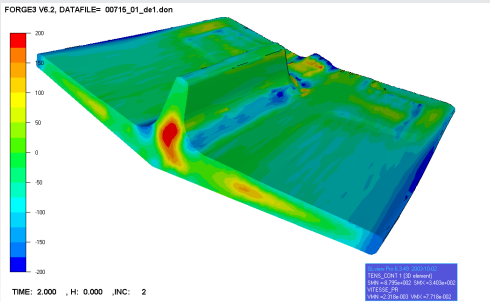
Up to 30 tons (66,000)
up to 7 meters (276") long

Co-engineering



Example of residual stress after quenching

- ▶ Simulation of complex, large, thick and seamless parts
- ▶ Leading expertise in residual stress - optimization and control of stress relief:
 - Allows parts to be machined without constraints
 - Allows you to eliminate the roughing and straightening steps
- A&D offers its support at the earliest stage in your development with:
 - Metallurgical know-how to obtain best mechanical properties (LH2, High T°...)
 - Co-design & input weight reduction



Example of residual stress elimination after cold-work

Main data

Closed-die forgings:

- ▶ Diameter up to 2 m / 79 in
- ▶ from 20 kgs / 44 lbs up to 13,000 kg / 28,600 lbs

Open-die forgings:

- ▶ up to 30,000 kg / 66,000 lbs

Bars

Main sizes

	mm	inches
Round Bars	Ø 7.5-500	Ø 0.30-20
Flat & Square Bars	T ≤ 310	T ≤ 12
Sheets	0.6 ≤ T ≤ 150	0.2 ≤ T ≤ 6

Surface conditions

- ▶ Black
- ▶ Peeled
- ▶ Ground
- ▶ Others

Heat treatment conditions

- ▶ Annealed
- ▶ Hyperquenched
- ▶ Normalized
- ▶ Heat solution treated
- ▶ Heat treated
- ▶ Aged

Innovation

We continuously develop new processes and grades to help face the challenges of the space industry.

HPS ML340

Duplex hardening grade specifically adapted for high temperature turbine shafts (450°C/840°F), requiring 2230 MPa/323 Ksi resistance. Benefits: weight savings, improved engine efficiency & gas consumption.

NiSA AD730®

Fully innovative nickel-based superalloy withstanding higher temperatures (750 °C / 1,382 °F) while reserving strength, creep and fatigue resistance at a competitive cost.

AI Aluminum-Lithium alloys

Allowing weight gain up to 4% with static properties equivalent or higher than 7010/7050 & improved fatigue and rigidity properties over 10%.

PM ABD®-900AM®, ABD®-1000AM® and AD730® (see pages 6-7)

AUBERT & DUVAL

A complete metal powder offer for additive manufacturing

PM Main materials

NiSA Nickel-based superalloys

ABD®-900AM®
 ABD®-1000AM® NEW
 AD730®
 HX
 InvHard
 Ni247
 Ni625
 Ni718
 Ni738
 X15TN® NEW

* : in partnership with Alloyed



Over the years, Aubert & Duval has acquired a deep and thorough knowledge in the design and optimization of metal powders in order to meet customers' most stringent requirements, particularly for air industry and space applications. We support space equipment manufacturers in achieving success in powder development for series production in their additive manufacturing.

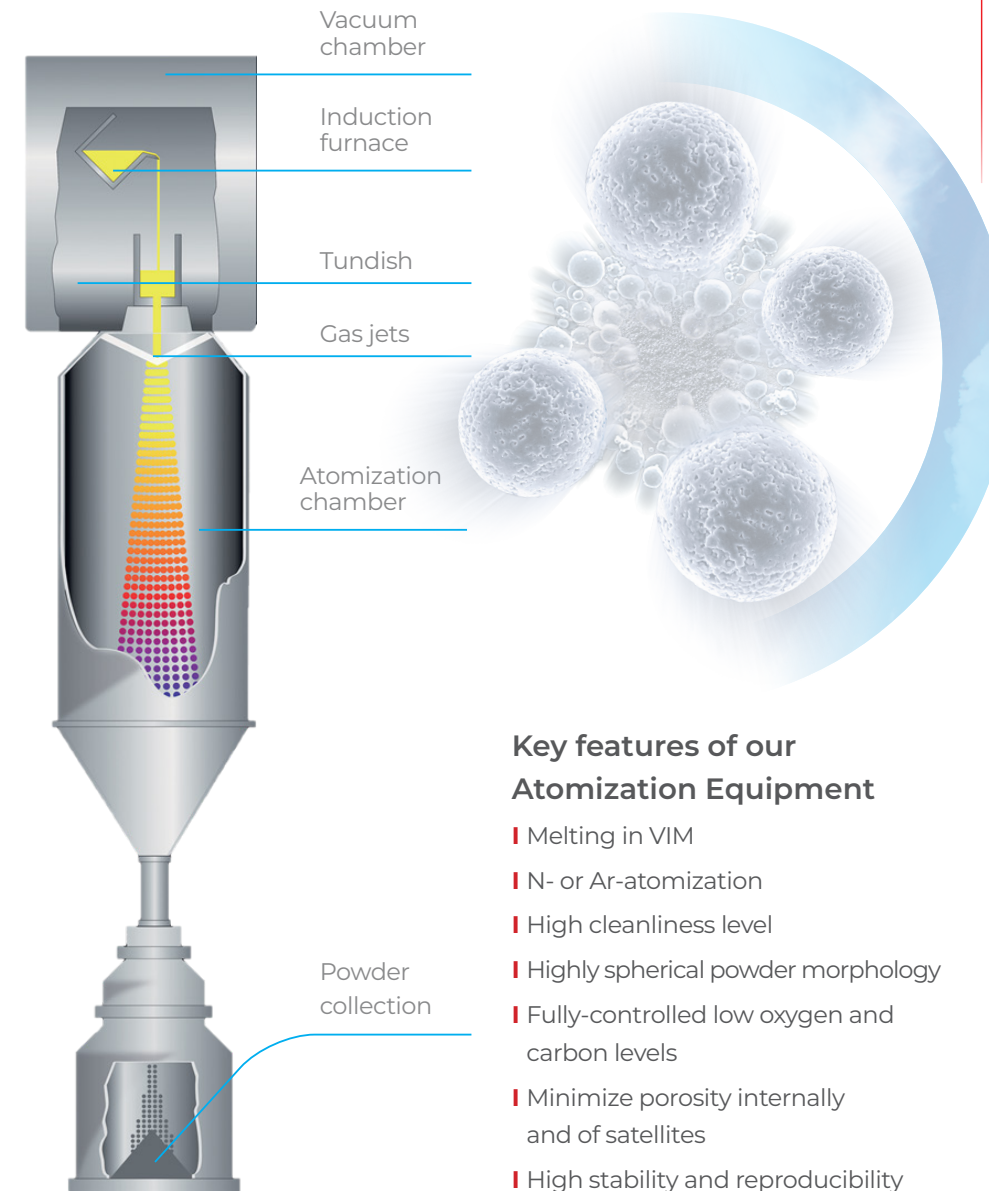
Our research centers and development teams are dedicated to developing new alloys and optimizing powder characteristics to achieve the best material performance and processability for all additive manufacturing technologies.

The performance of our powders at the heart of your additive manufacturing success

Thanks to our long-standing experience serving the space industry, we can offer tailored metal powder, including design of the chemical and mechanical properties, in accordance with space requirements.

We help our customers in the definition of metal powder specifications in order to develop suitable solutions for space applications for propulsion and structural parts for use at higher temperature and for higher trust & weight savings.

Our Atomization Process



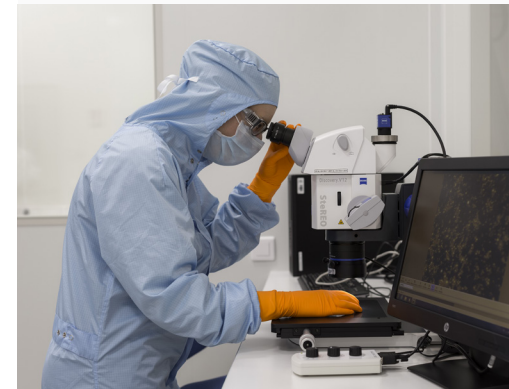
Key features of our Atomization Equipment

- Melting in VIM
- N- or Ar-atomization
- High cleanliness level
- Highly spherical powder morphology
- Fully-controlled low oxygen and carbon levels
- Minimize porosity internally and of satellites
- High stability and reproducibility

Quality Control

With 40 years of experience in high quality gas-atomized powders, Aubert & Duval has a high level of expertise and also dedicated laboratory equipment ensuring the highest quality for powders:

- Powder size distribution: by sieving and laser diffraction
- Morphology: SEM pictures
- Chemical composition: ICP, GDMS & fusion
- Absorption Spectrometer (GFAAS)
- Other physical properties : density, flowability

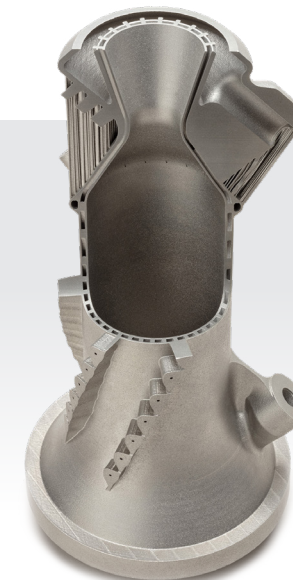


Quality and certifications

- EN 9100
- ISO 9001
- Customer accreditations

Powder sizes

Laser Beam Melting:
 • 10-53 or 15-63 µm
 Electron Beam Melting:
 • 45-106 µm
 Direct Energy Deposition:
 • 45-90 µm
 Customized particle size distributions available upon request



Powders for AM Technology

Our metal powders are designed for the full range of additive manufacturing processes:

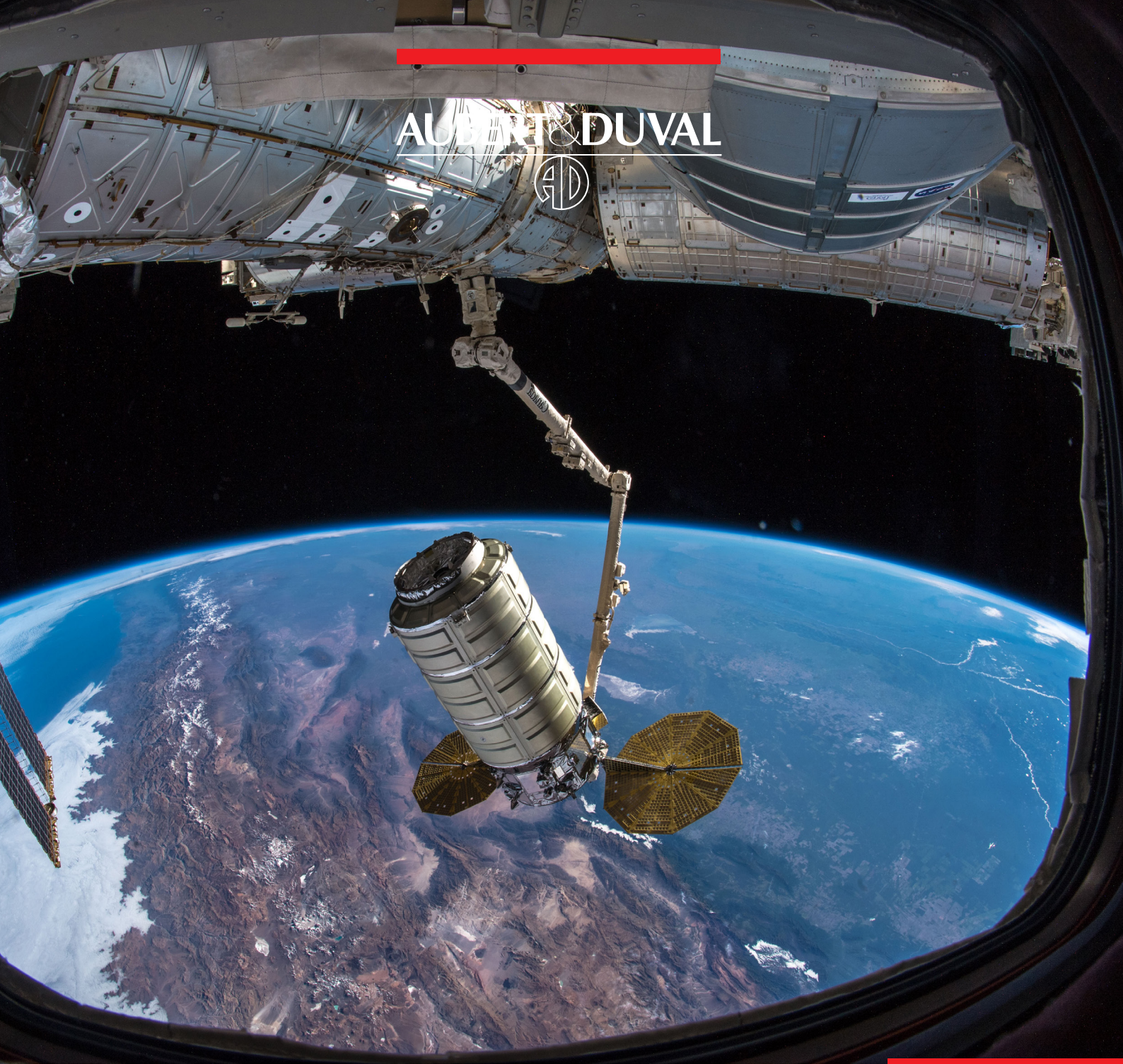
Powder Bed

- Laser Beam Melting
- Electron Beam Melting
- Binder Jetting & Sintering

Blown Powder

- Laser Metal Deposition
- Cold Spray

Combustion chamber for rocket engine. ABD®-900AM® powder inside. Courtesy of Airborne Engineering, Alloyed and Renishaw



AUBERT & DUVAL



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