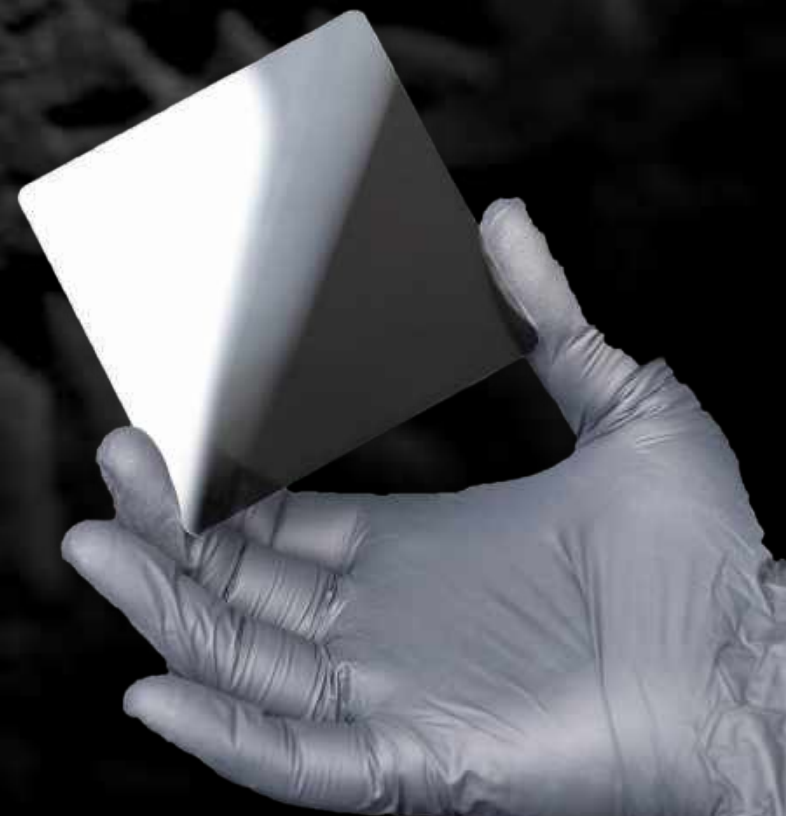
# Ceramic Nano Memory

## Data Storage for the Yottabyte Era

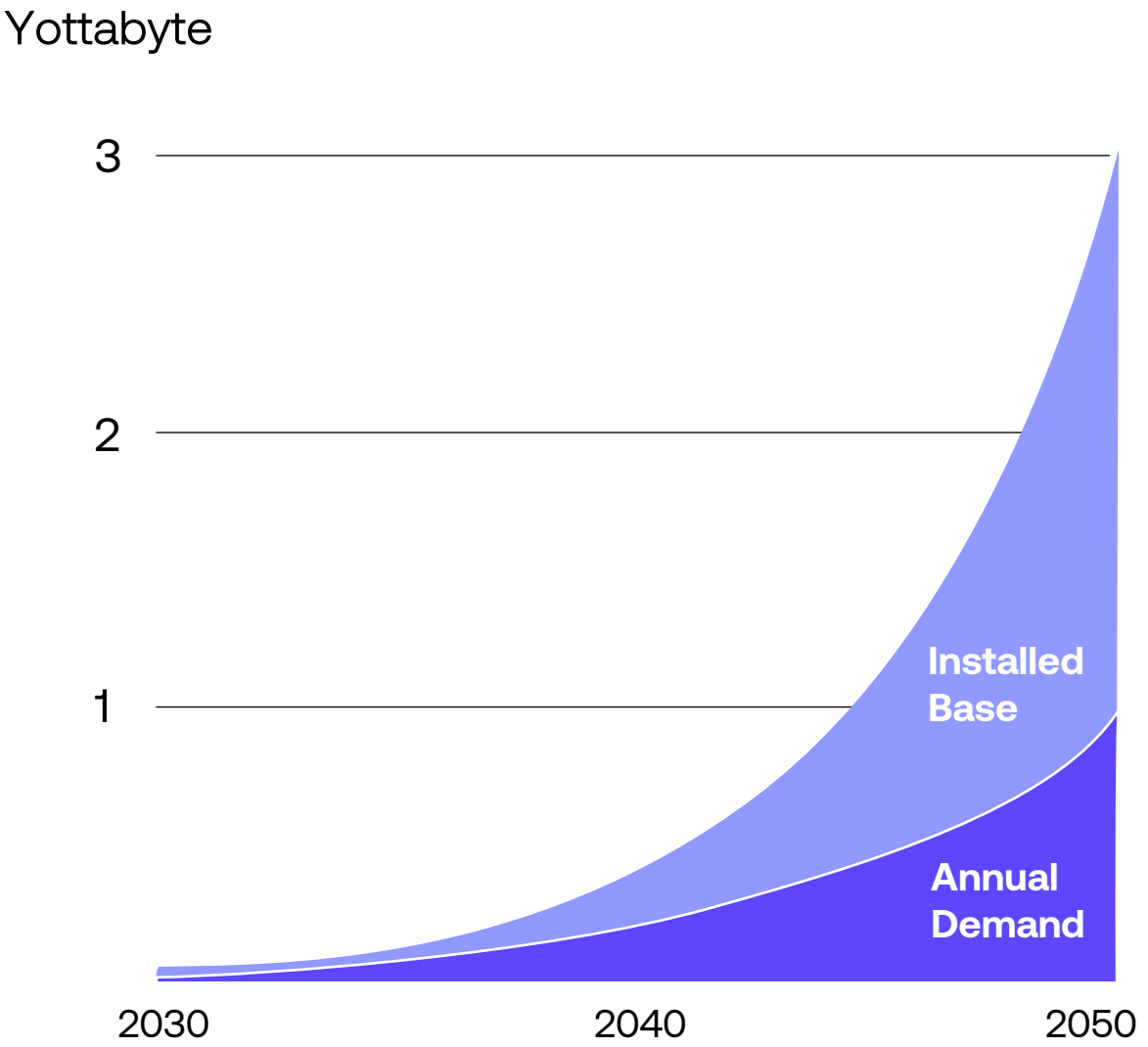


Christian Pflaum, CEO - Cerabyte

# Data storage explosion

Innovations likely to drive installed base & demand in 2040s beyond

**1 Yottabyte**

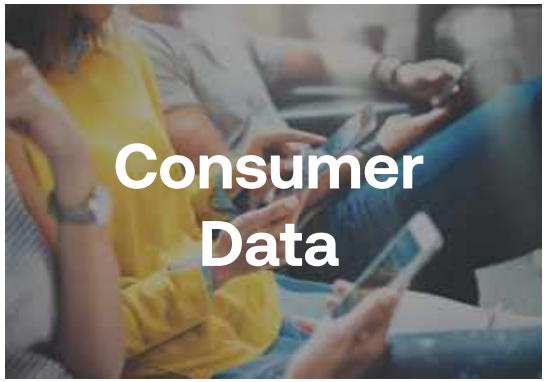




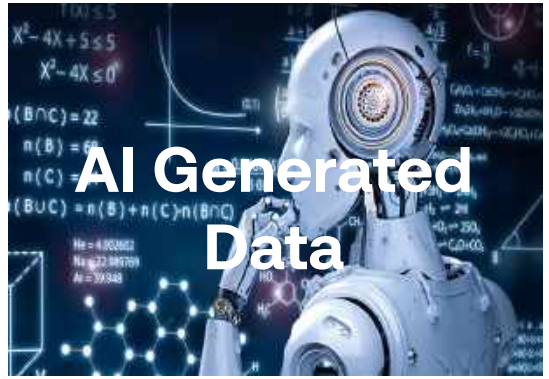

Source: Furthur Market Research 2022-2030 – Assumption: 25% CAGR 2030-50

# Cold data challenge

**>70%** of all data is **cold**
rarely retrieved after **90 days**
but stored for more than **a decade**





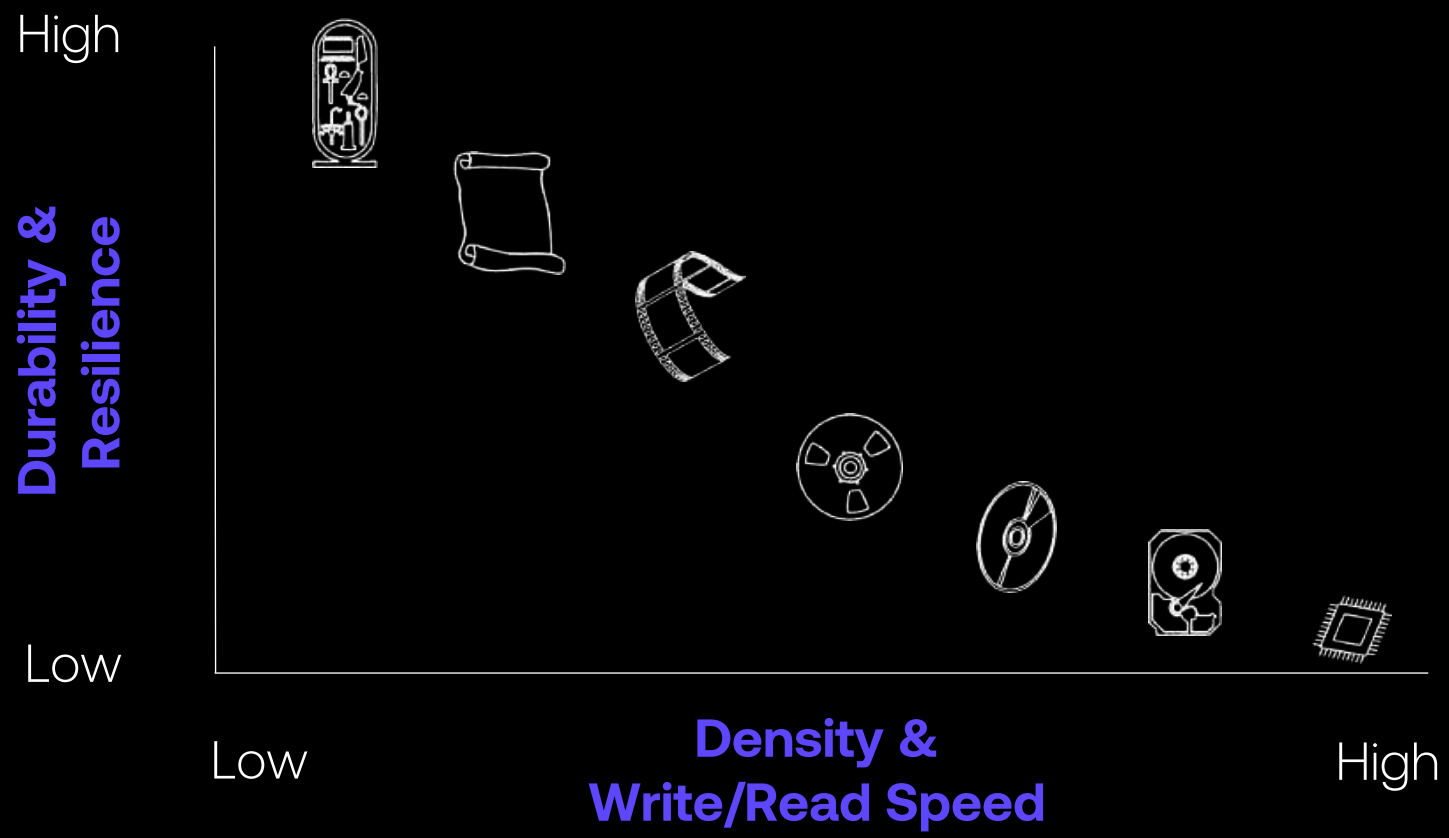
1 Yottabyte = $10^{24}$ Byte

# AI – Art & Facts

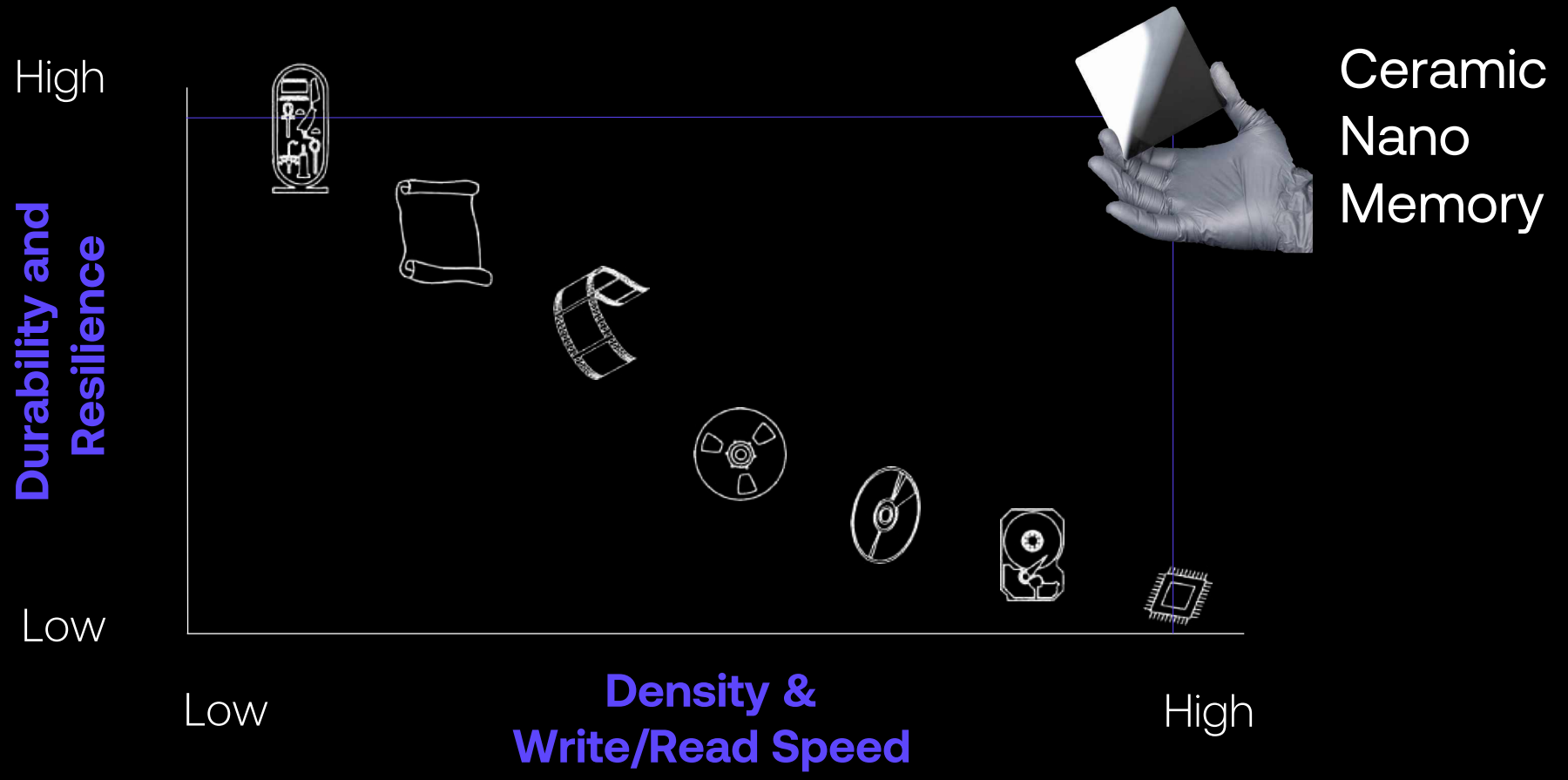
about life, the universe & everything

| **AI key words** | **Real world facts** |
|---|---|
| Stars | $10^{24}$ |
| Humans (by 2050) | 10 bn |
| Brain (map) | 1,4 ZB |
| DNA (genome) | 3,2 Gbp |
| Atoms | $10^{80}$ |

# Density & Speed **Scaled Up** while Durability & Resilience **Scaled Down**



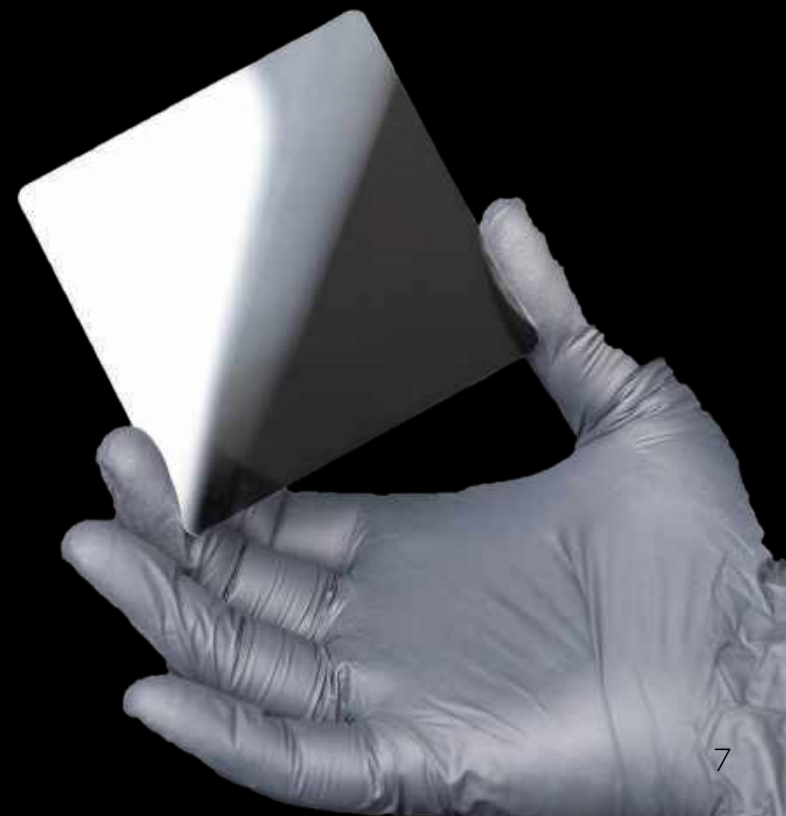
# Ceramic Nano Memory combines density & speed with extreme durability & resilience



# First Principle

## Extremely durable material

instead of electric charge or magnetic polarization



# Inspiration

## Data have been carved in stone & ceramic for 5,000 years

### Rosetta stone
Egypt

2,200 years

Governmental
Data

### Gilgamesh Drama
Babylon

3,800 years

Media
Data

### Beer Receipt
Mesopotamia

5,000 years

Business
Data

# Ceramic Micro Memory - Proof of concept of 25,000 years

Rosetta stone
Egypt

2,200 years

Governmental
Data

Gilgamesh Drama
Babylon

3,800 years

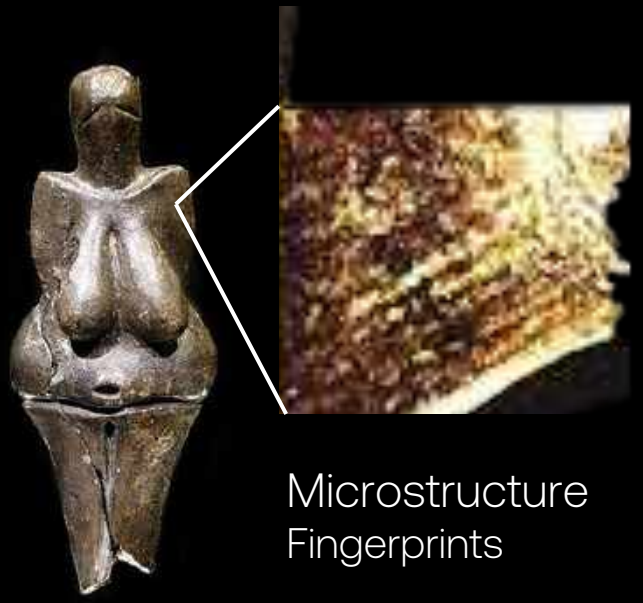
Media
Data

Beer Receipt
Mesopotamia

5,000 years

Business
Data

Venus Sculpture
Europe



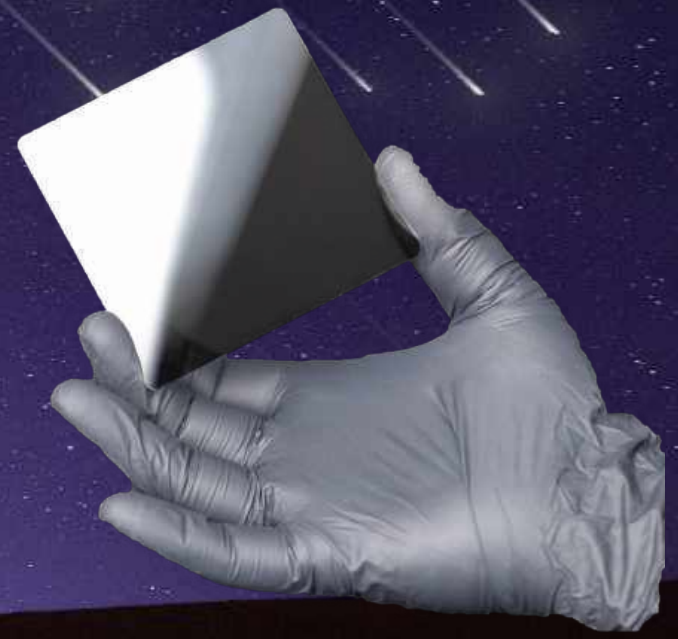
Microstructure
Fingerprints

25,000 years

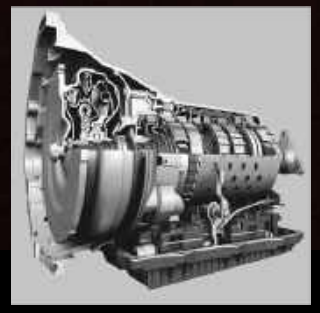
Consumer
Data

# 4.5 B year old meteorite material sparked our innovation

## Meteorite material



4.5 bn years
heat resistant



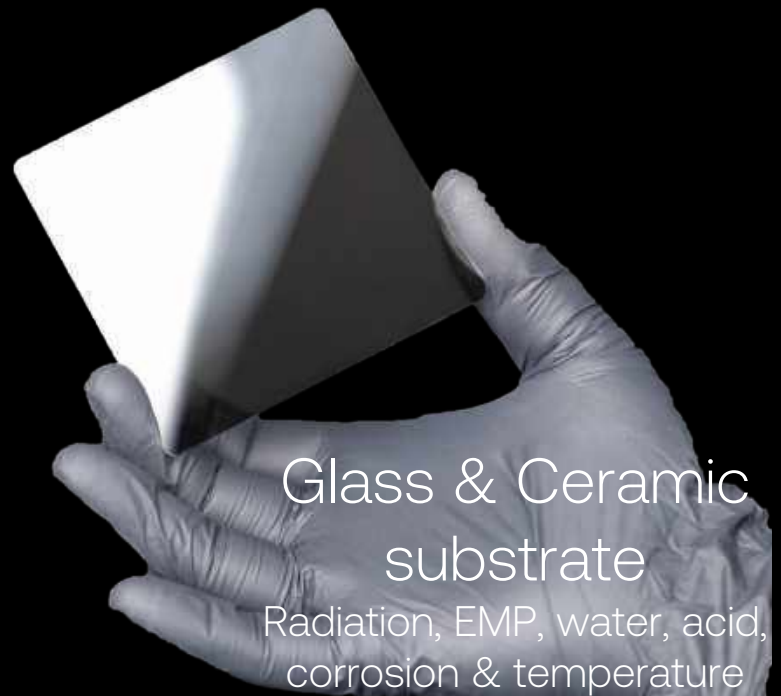
Design

# Ceramic materials enable virtually **unlimited** media life

Meteorite – Material

Vapor Deposition
of Metal Nitride coating

**Metal nitride coating**
Radiation, EMP, water, acid,
corrosion & temperature
resistant up to 1200° C



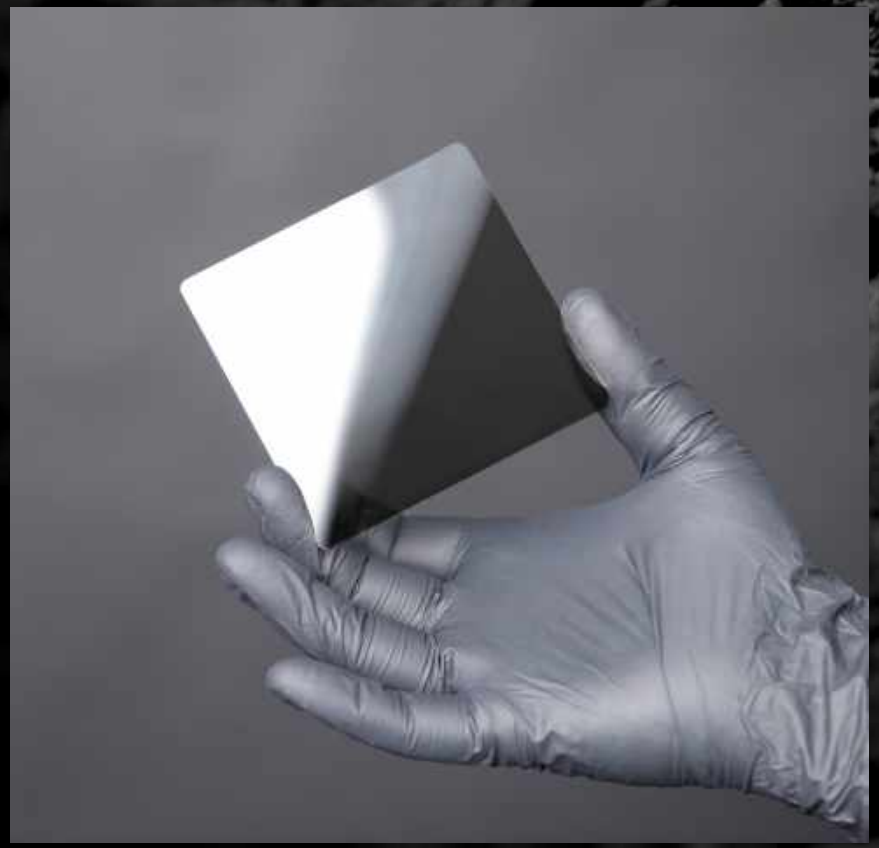
Glass & Ceramic
substrate
Radiation, EMP, water, acid,
corrosion & temperature
resistant between 500-2500° C

Flexible Glass & Ceramic

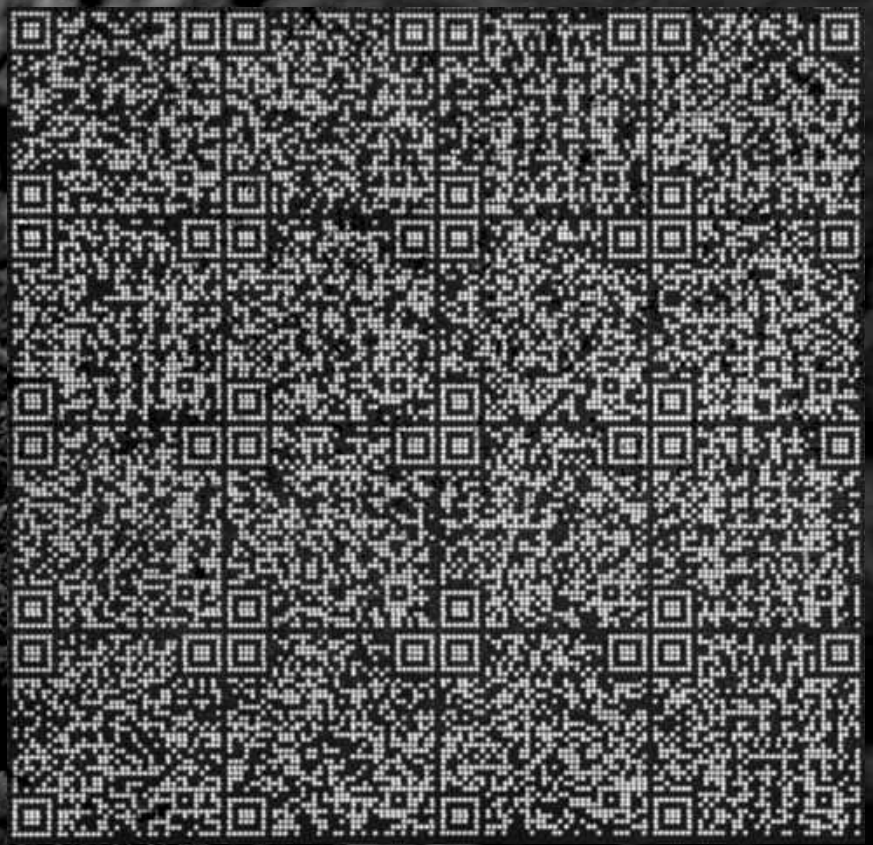
**Flexible glass** surface roughness < 1 nm

**Flexible ceramic** consists sintered nano particles

# Ceramic nano-coating and laser nano-structuring



+



Ceramic nano-coating

Laser nano-structuring

# Production methods

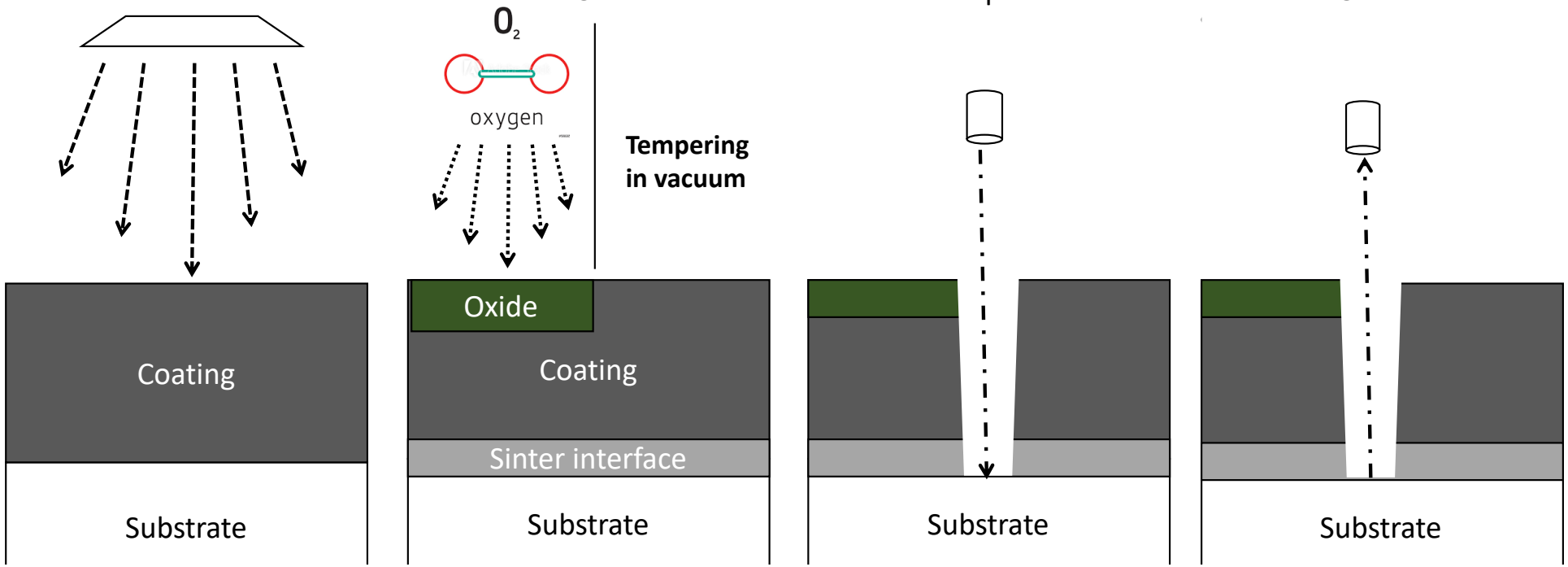
## Sinter interface built by tempering between coating & substrate

**Step 1: Thin film coating**
- PVD
- CVD
- Sputtering

**Step2: Tempering**
- Oxidation (surface area)
- No oxidation (in vacuum)
- Sintering (interface area)

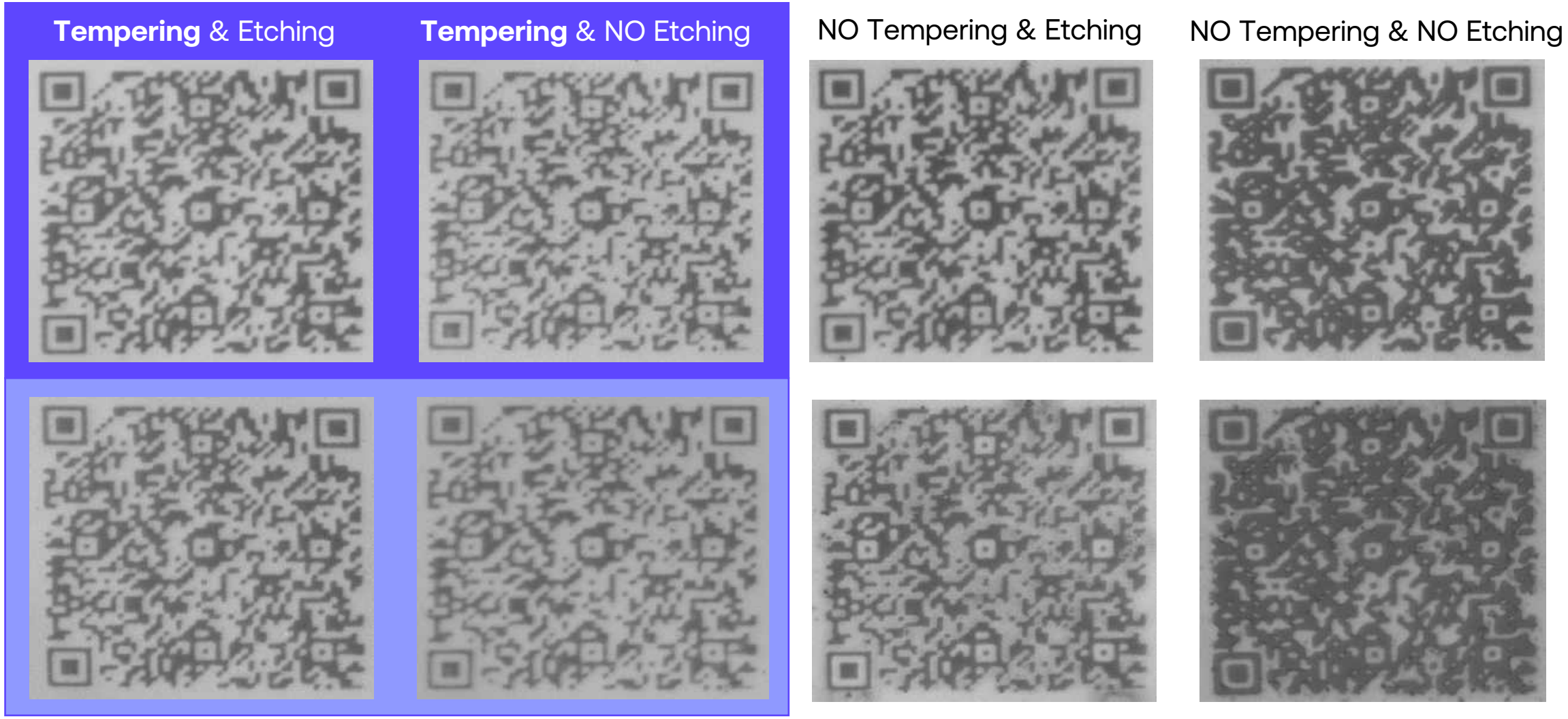
**Step3: Write either with**
- Laser or
- Ultra-short-pulse laser
- Focused particle beam

**Step 4: Read either with**
- Digital Scanner
- Laser Scanning Microscope
- Scanning Electron Microscope



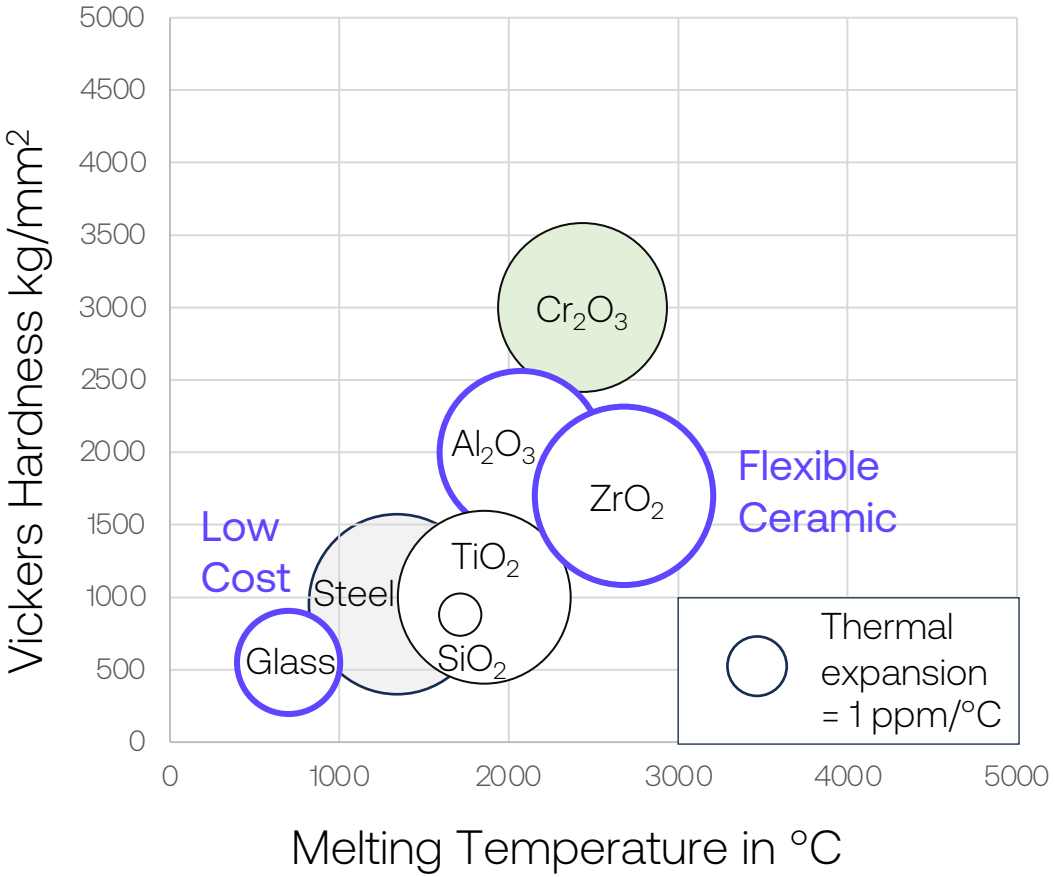

## Nanoscale writing & reading enabled by laser or particle beam

# Tempering generates superior results before & after aging

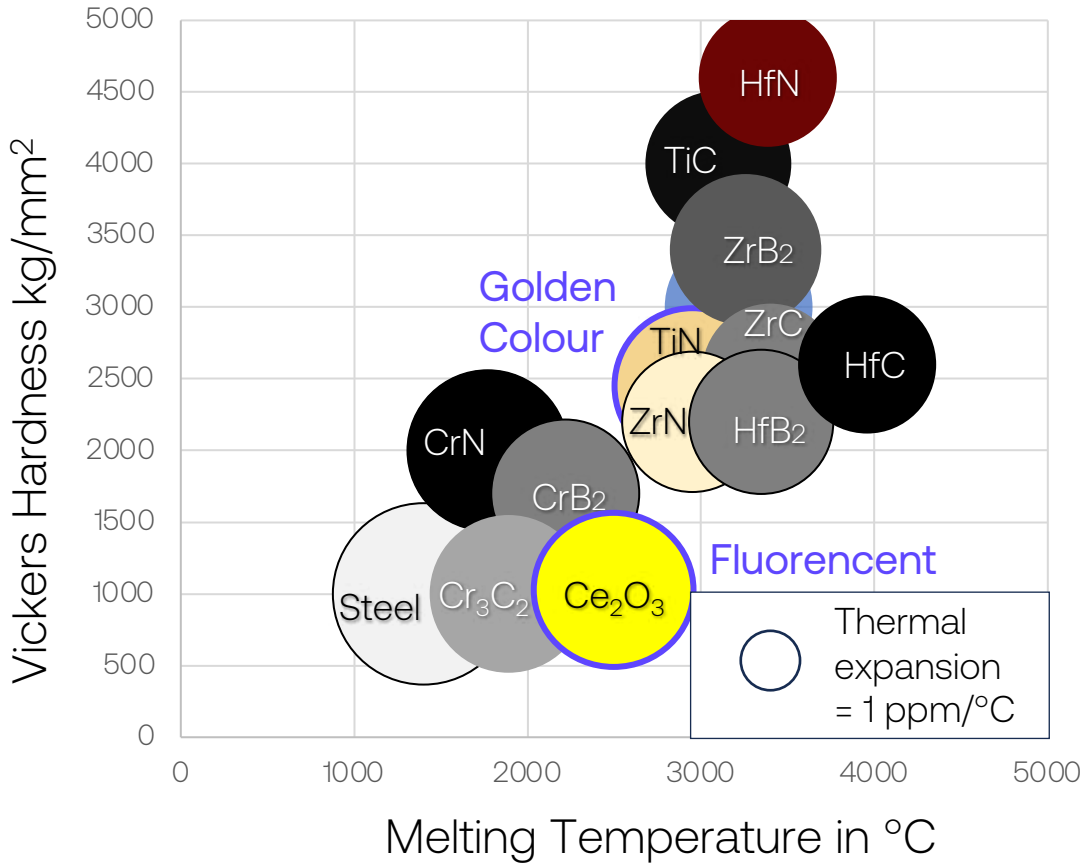


# Ceramics are harder & more temperature resistant than steel

## Transparent Substrate Material




## Absorbing Coating Material



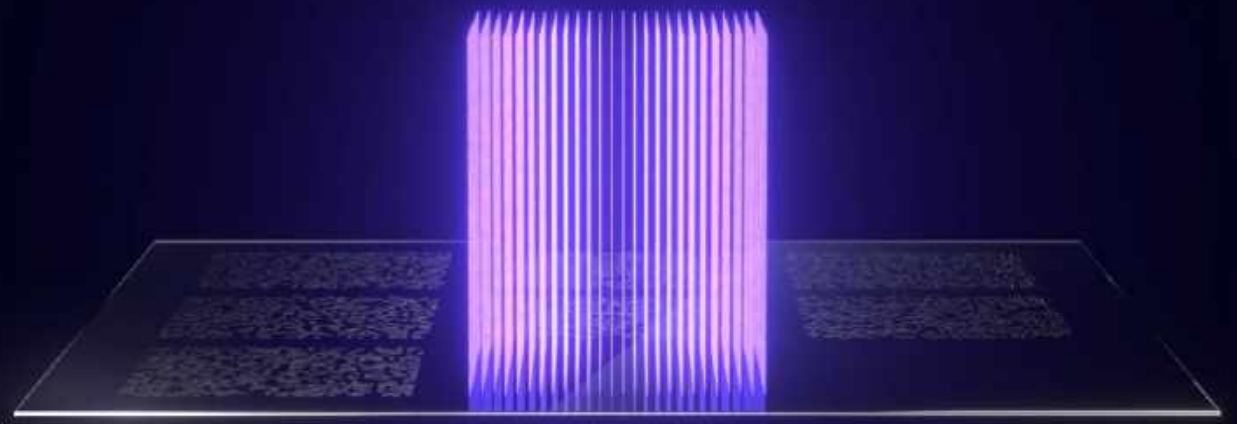

A wide range of material combinations enable various designs

# Glass substrate - Temperature, EMP, UV and radiation resistant

| | - 273 °C ( 80 mK) | 3 days @ 300°C - air | 3 days @ 500°C – $SO_2$ | EMP, UV & radiation |
|---|---|---|---|---|
| Before Aging |  |  |  |  |
| After Aging |  |  |  |  |

# Data Media Design

# Second Principle



Watch Video https://vimeo.com/859682540/34a6d3e02b

Speed with
Laser Matrix

up to 2 million
bits in one shot

# Inside the monolith

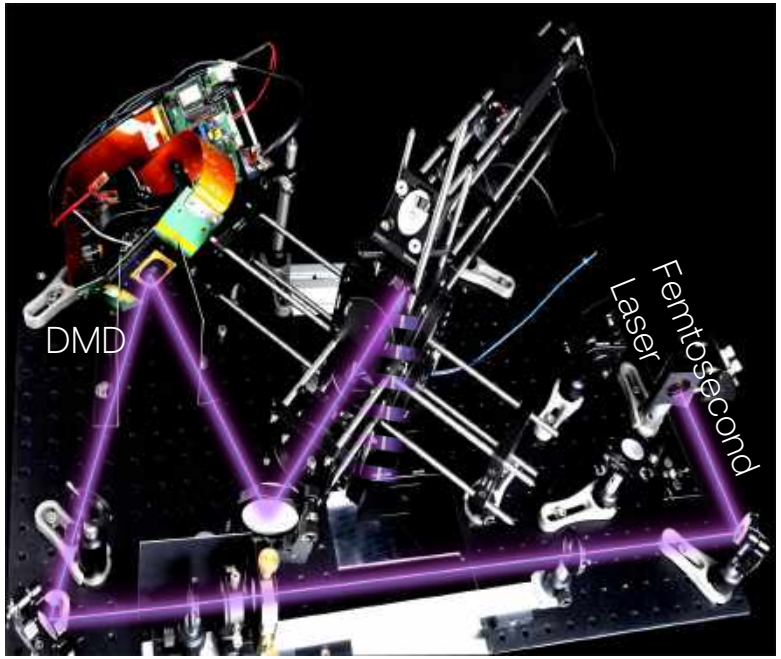
https://vimeo.com/841629751



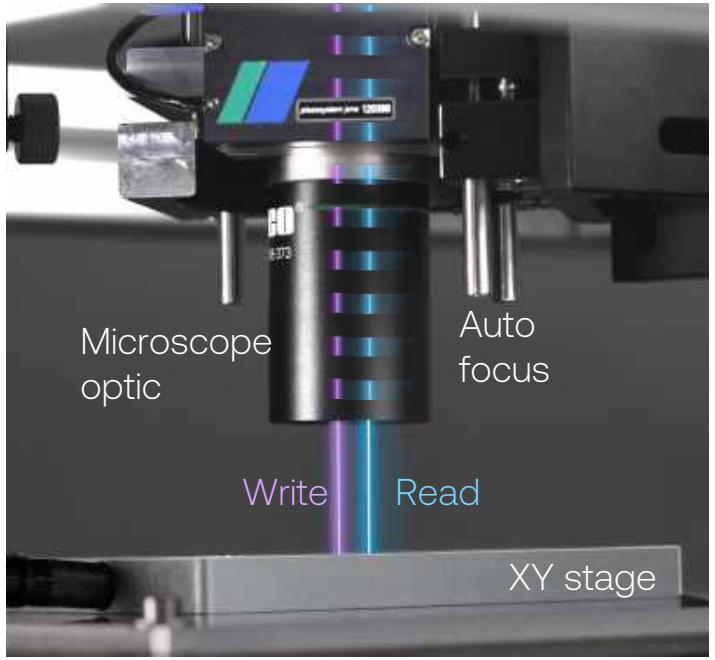
Watch Video https://vimeo.com/841629751

# Inside the monolith

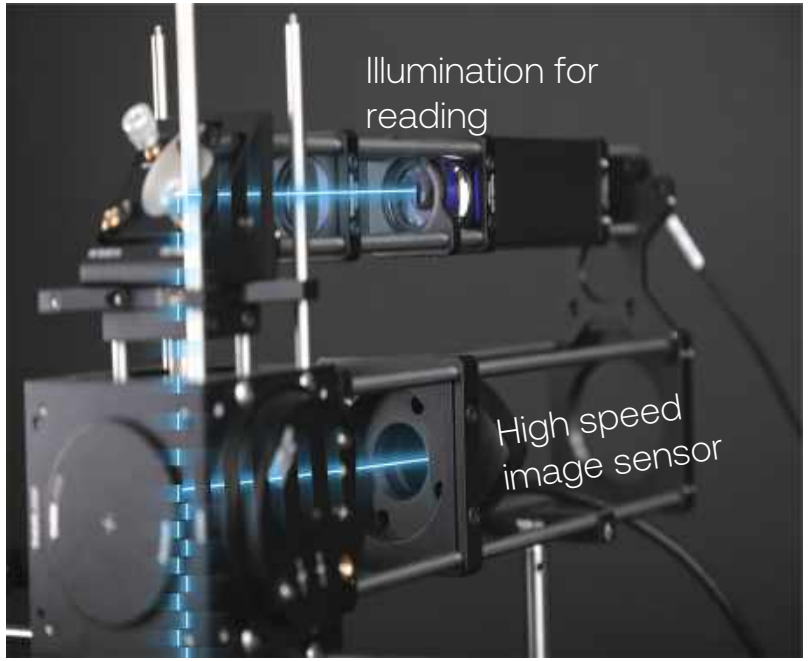
High-speed laser writing with DMD




Microscope optic for writing & reading



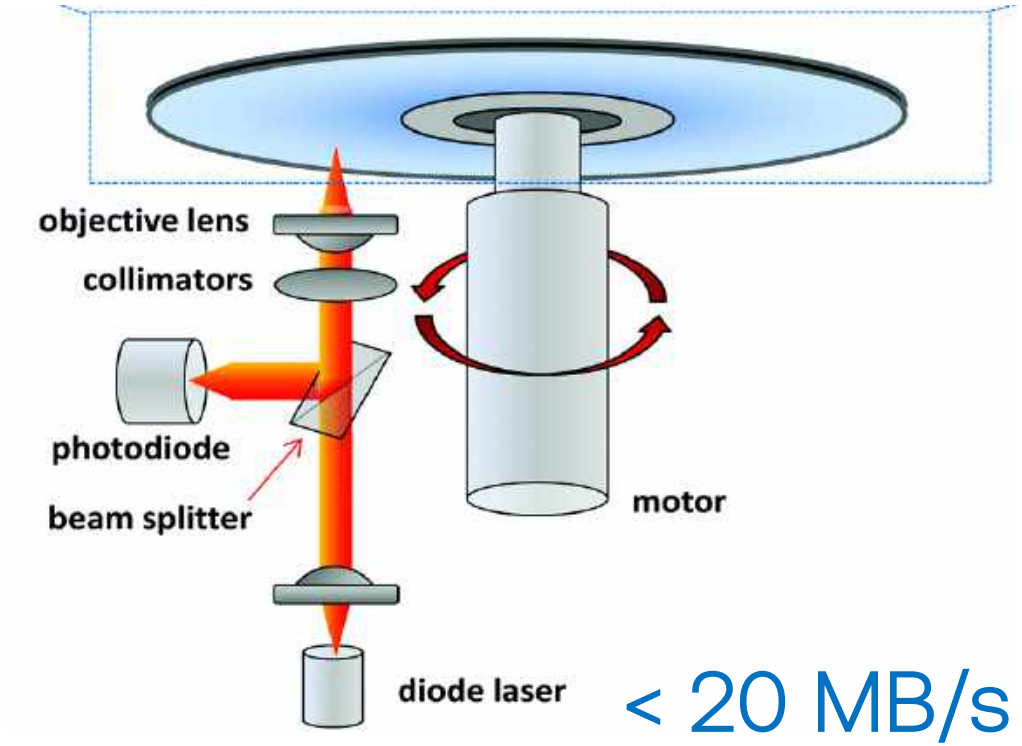

High-speed reading via image sensor



# Speed comparison

## Laser beam matrix is at least 50 x faster than optical disc drive

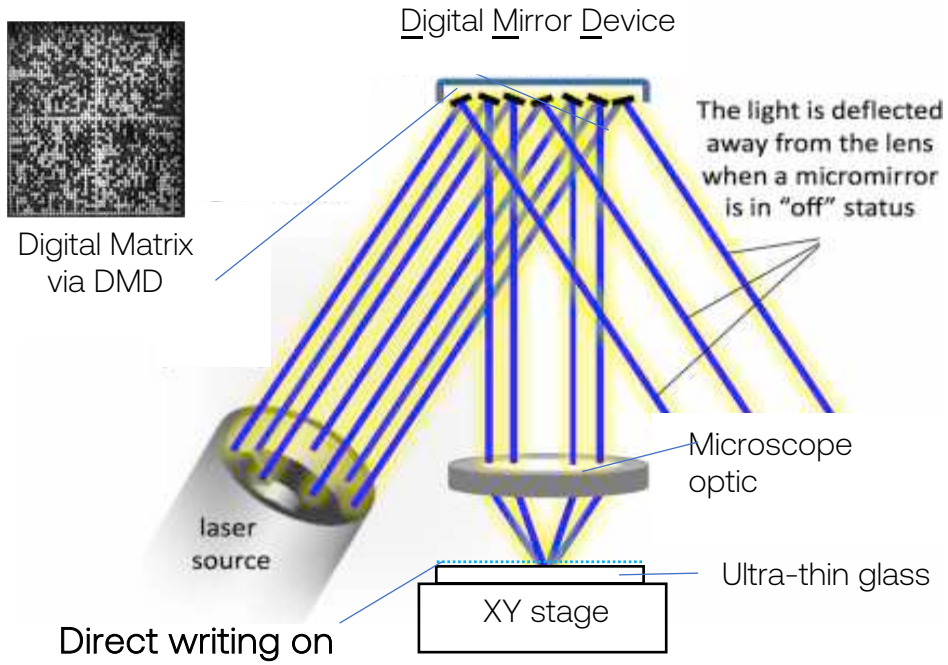
### Optical Disc Drive




< 20 MB/s

Speed limitation due to centrifugal forces

### Laser Beam Matrix




1+ GB/s

DMDs enable further speed improvements

# Third Principle

3,000 BC

# High Density Matrix Code

2023 AC

# Modern matrix code utilizes full surface area of medium

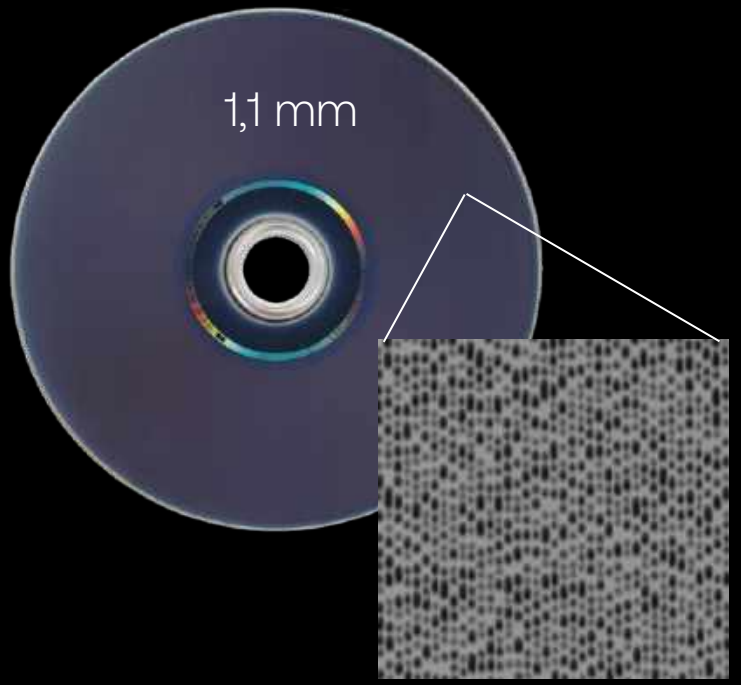
## Cuneiform Code
Mesopotamia

3,000 BC – 75 AC

## Alphabetic Code
Mediterranean

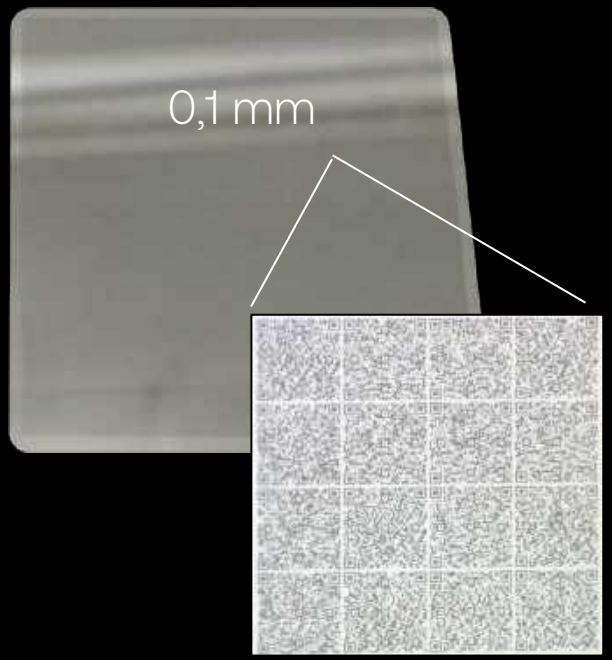
1,000 BC – 1900 AC

## Binary Code
Optical Disc




1980 AC – today

## Matrix Code
on cerabyte



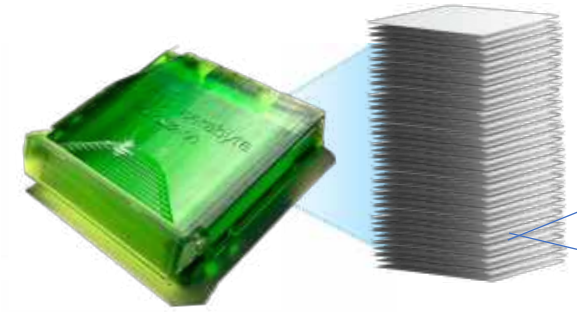

2023 AC

# Higher Data Density

## Matrix coding & thinner substrates enable 50x higher data density

### Cartridge volume

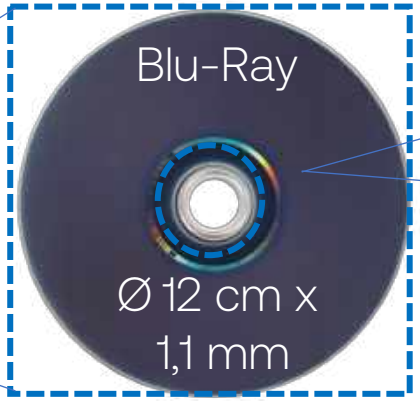

132 x 130 x 26,7 mm³



102.0 × 105.4 × 21.5 mm³

x 2

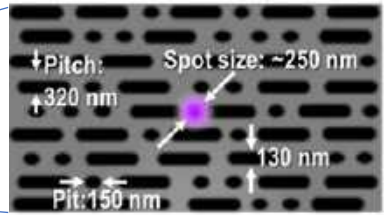
### Data carrier thickness



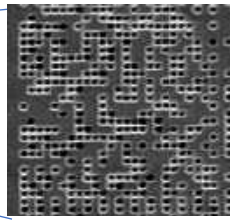

Ceramic
Nano Memory
9 x 9 cm
100 µm

x 11

### Data density




Layers: 4 layers
Track pitch: 320 nm
Bit length: 150 nm

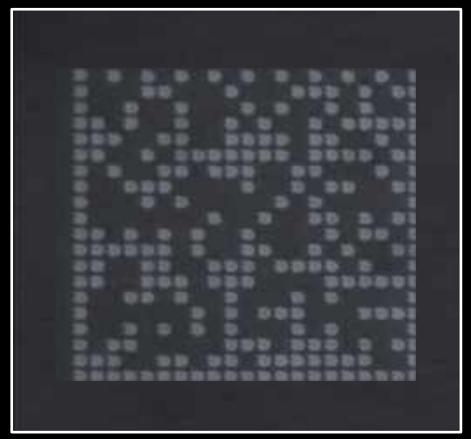
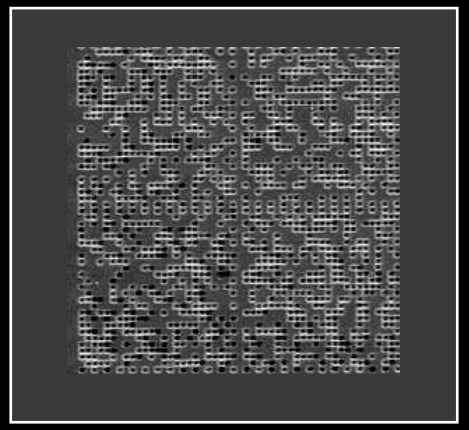


Layers: 2 layers
Bit width: 100 nm
Bit length: 100 nm

x 2.4

Proof of Concept

# Cerabyte demonstrated 1+ TB per 100 $cm^2$ in PoC studies

| | Nanosecond Laser | Picosecond Laser | Femtosecond Laser | Particle Beam |
|---|---|---|---|---|
| |  |  |  |  |
| Process size | 35 µm | 1,0 µm | 100 nm | 30 nm |
| Data capacity<br>per 100 $cm^2$ – 15,5 $in^2$ | 1,0 MB | 1,25 GB | 125 GB | 1+ TB |

# Fourth Principle

## Particle Beams

New frontiers 2030-45

# Nano-structures are created by laser or particle beam

## Laser Beam Matrix

Process size 1000 - 100 nm

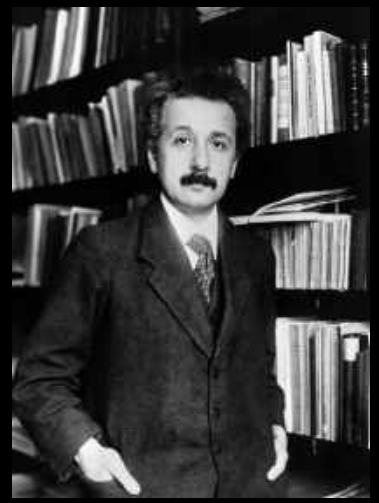
+

## Particle Beam Matrix

Process size 100 - 3 nm

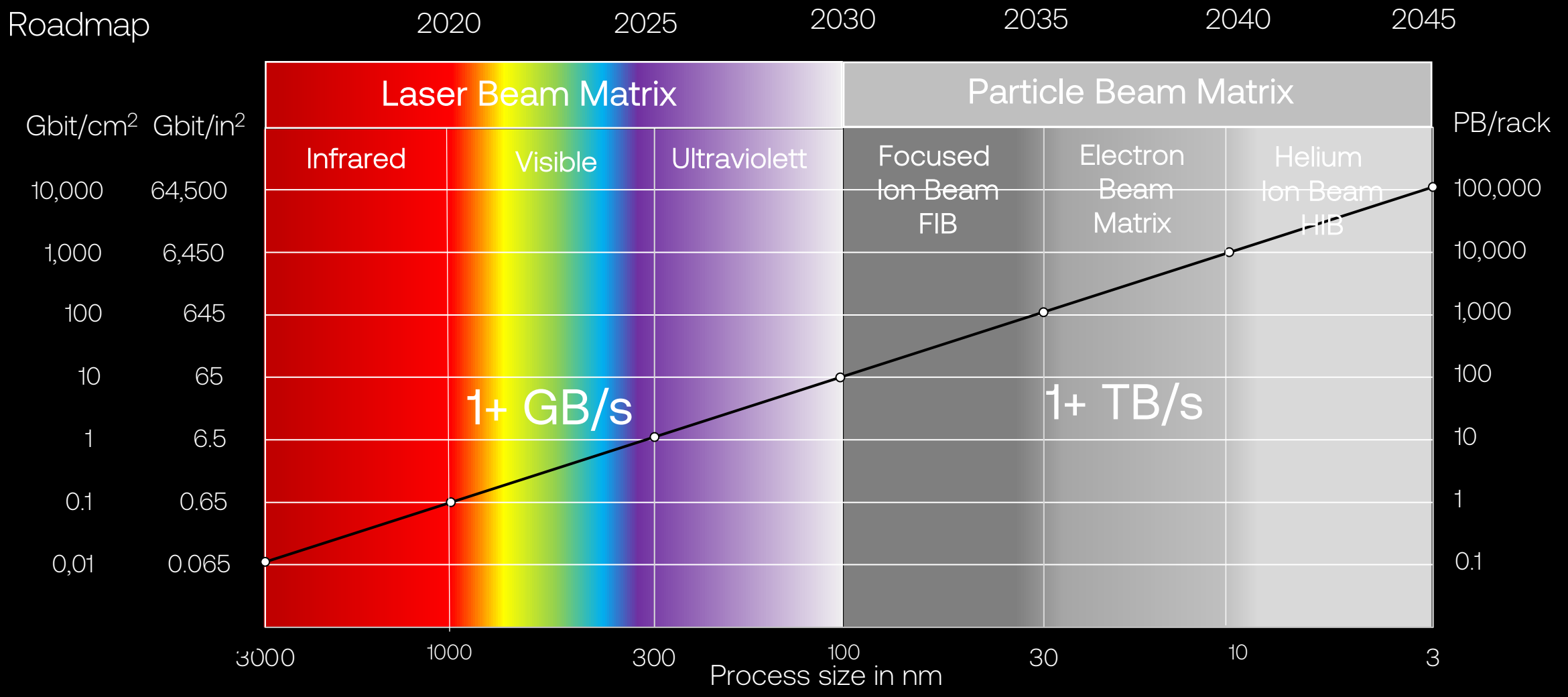
# Particle beams push the diffraction limit to nanometer scale

1000 nm — Light — 100 nm — Particle Beam — 1 nm

| Ernst Abbe | Max Planck | Albert Einstein | Louis DeBroglie | Manfred Ardenne |
|---|---|---|---|---|
|  |  |  |  |  |
| 1873 – Age 33 | 1900 – Age 42 | 1905 – Age 26 | 1924 – Age 32 | 1937 – Age 30 |
| $d = \frac{\lambda}{2 \sin \alpha}$ | $E = h \nu$ | $E = h \frac{c}{\lambda} = m c^2$ | $\lambda_e = \frac{h}{m_e v_e}$ | $d_e = \frac{\lambda_e}{2 \sin \alpha}$ |
| Diffraction limit | Quantum theory | Photo electric effect | Wave particle dualism | Electron Microscope |

Visionary Roadmap

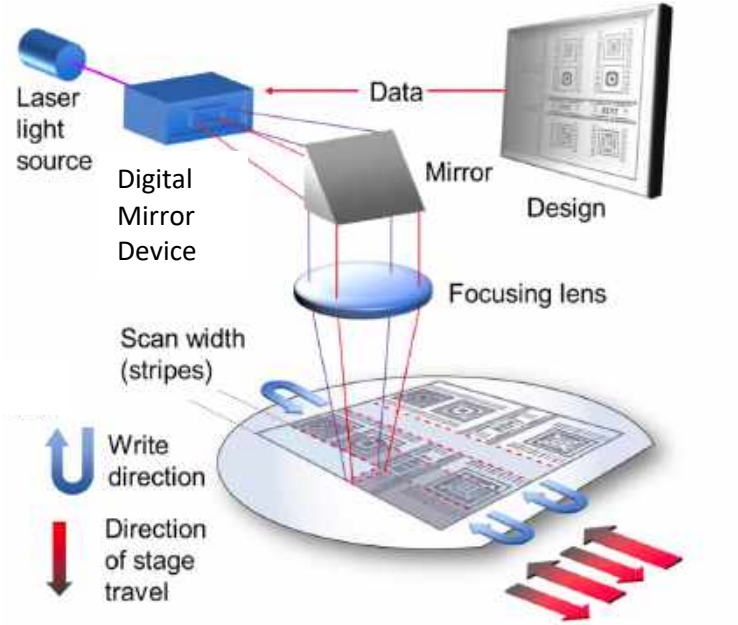
# Leveraging semiconductor technology to scale density and speed



# Fast track design

## Write/read unit was built on 19“ footprint in less than 12 months

| Maskless Lithography System | Working Principle | Ceraybte Write Read Unit |
|---|---|---|




WxDxH: 3000 x 4000 x 2200 mm

WxDxH: 600 x 1200 x 2150 mm

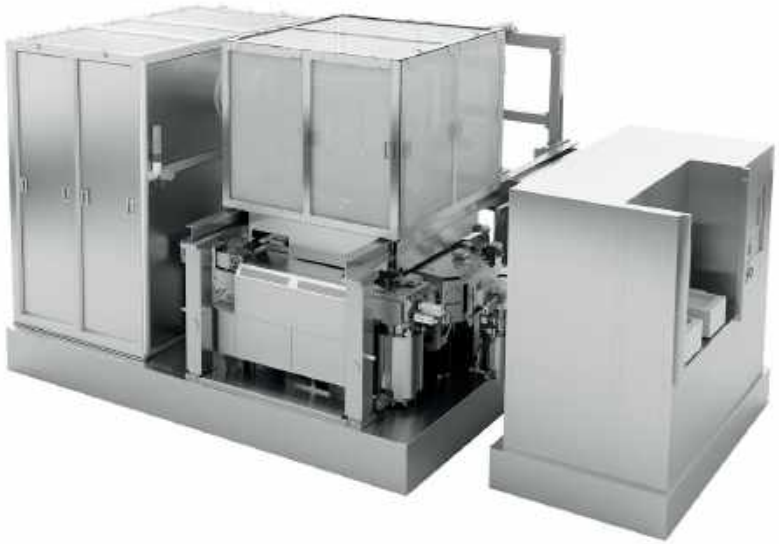
## Design inspired by maskless lithography systems available since early 2000s

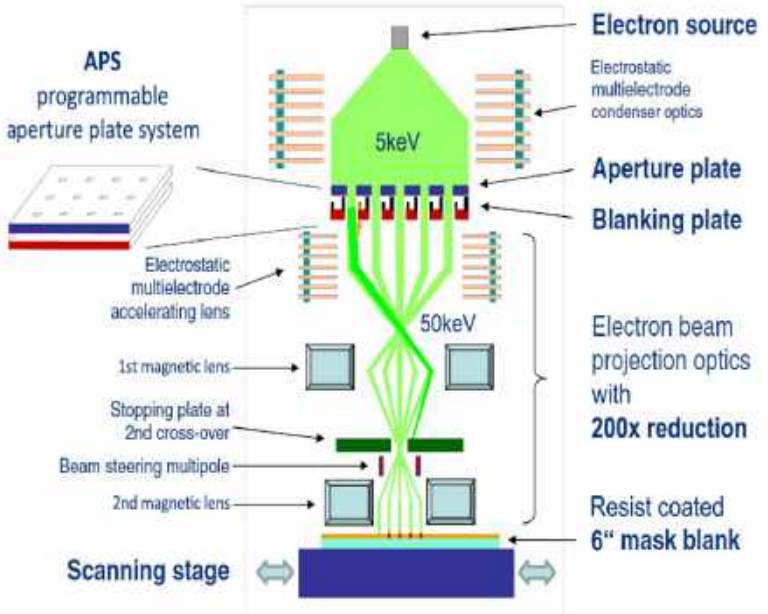
# Future design 2030 +

## Multi-Beam Mask Writer might serve as blueprint for future design

| Electron Beam Matrix | Working Principle | Future Design |
|---|---|---|

Beam matrix = 512 x 512
= 262,144 beams per shot






WxDxH: 5000 x 3000 x 2000 mm

WxDxH: 5x600x1200x2150 mm

**Node:** 28-5 nm - writing speed: 120 Gbits/s – planned: 1 Tbit/s - Too expensive today

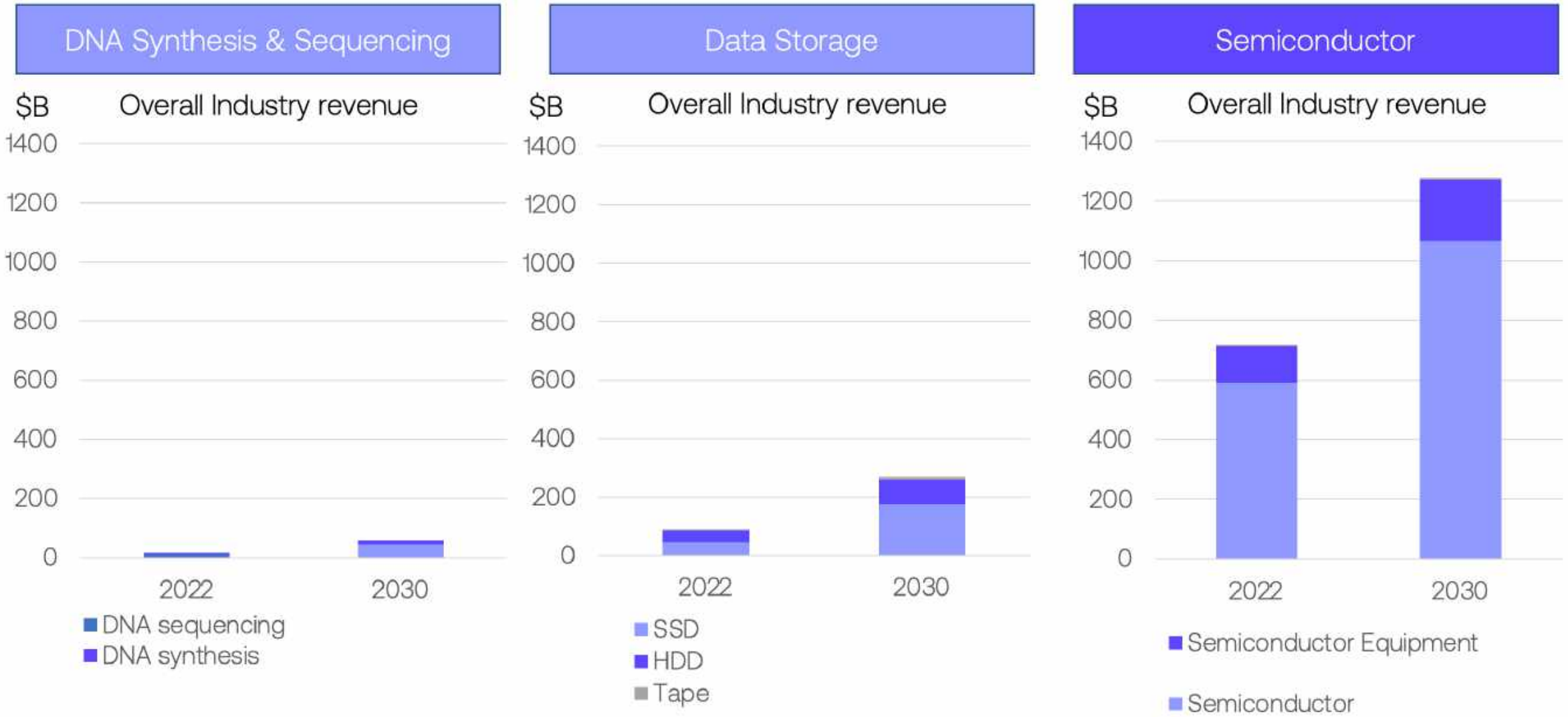
Multi-beam electron gun tubes have been sold in millions as

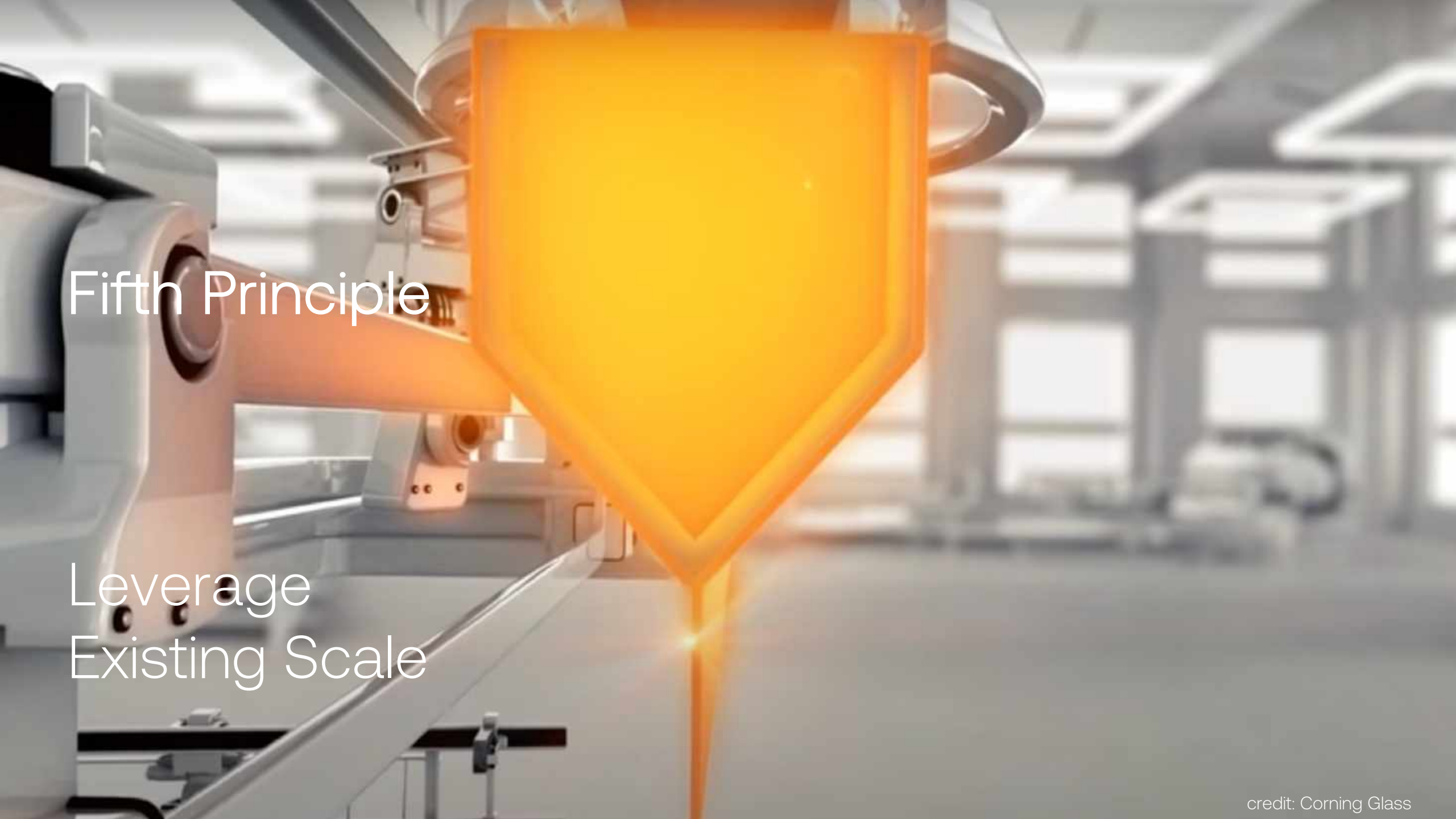
# Color TV-sets

AI-fiction: Frustrated astronaut watching mars landing on color tv-set in living room of 1970s.

# Innovation power

## Semiconductor industry best positioned to drive innovation

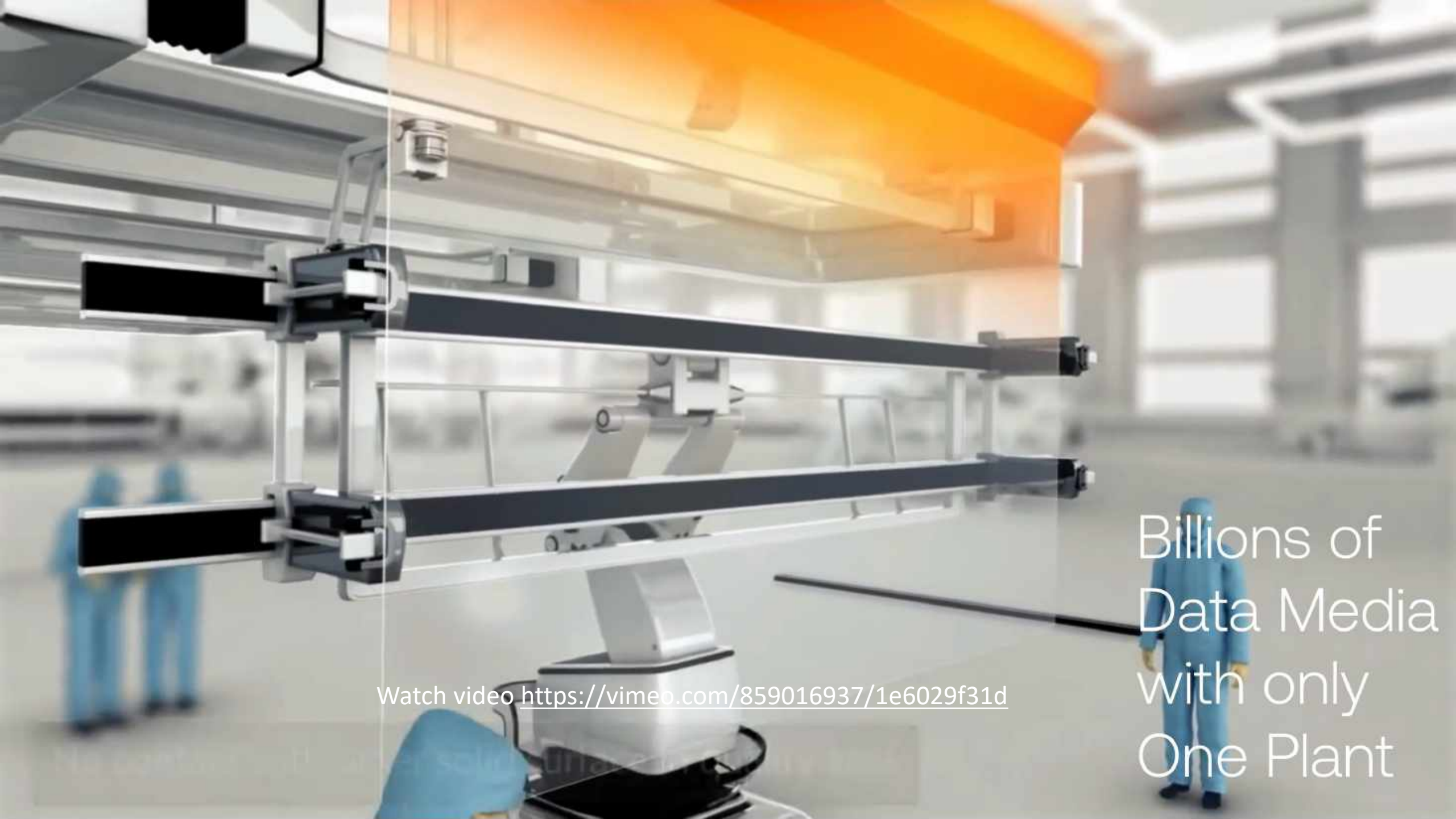




# Fifth Principle

## Leverage Existing Scale

credit: Corning Glass

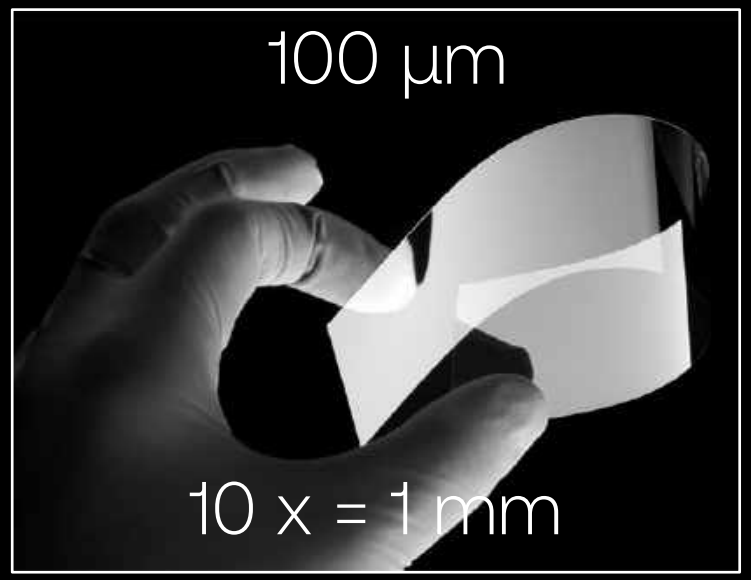



Watch video https://vimeo.com/859016937/1e6029f31d

# Future Scaling Options

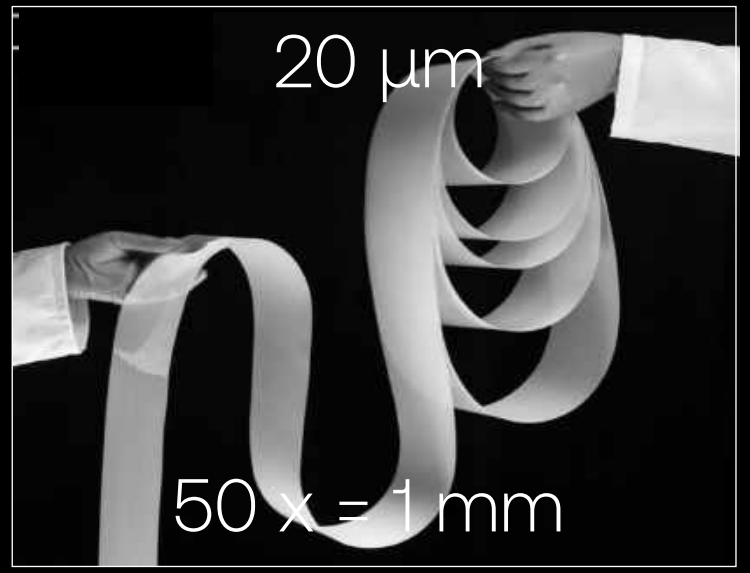
## Substrate type extends field of application & volume density

Flexible ultra-thin glass



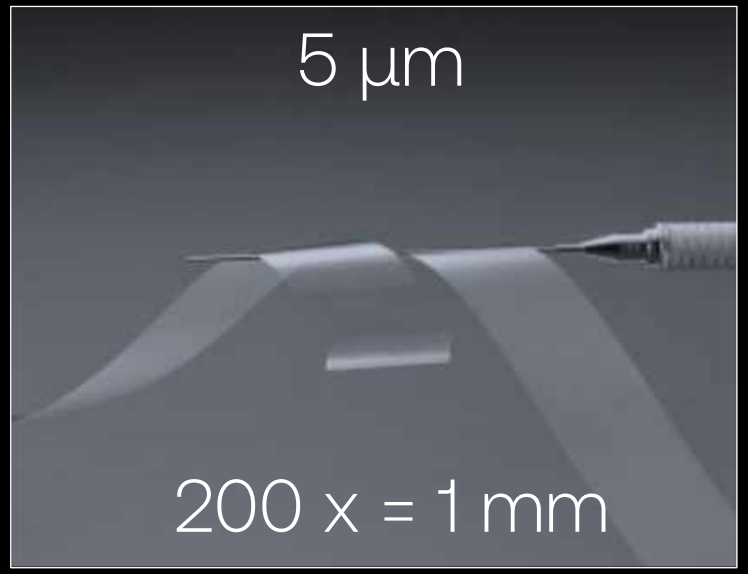

CeraMemo

Ribbon ceramic



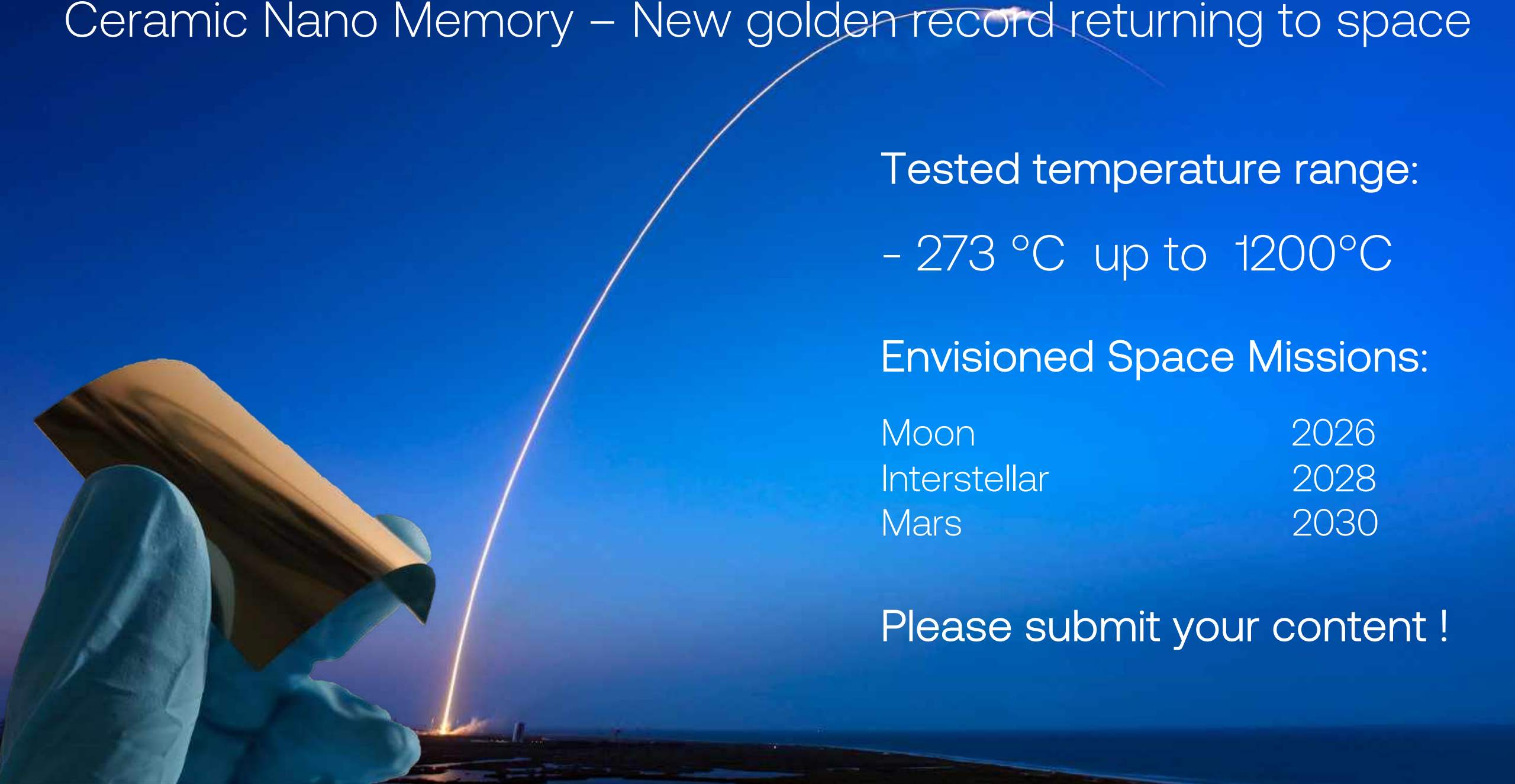

CeraSpace

Ribbon glass




CeraTape

# Ceramic Nano Memory – New golden record returning to space



## Tested temperature range:

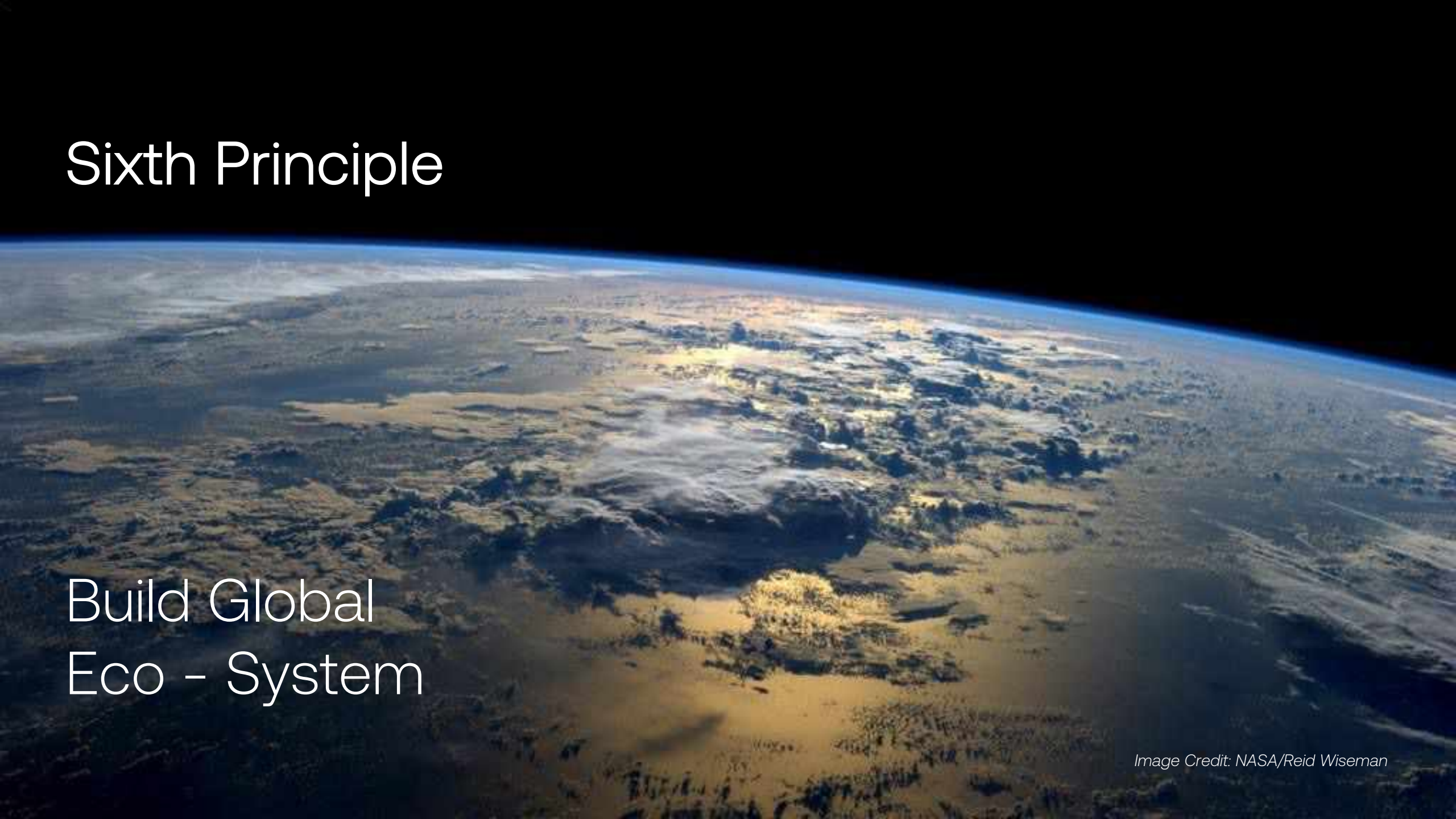
- 273 °C  up to  1200°C

## Envisioned Space Missions:

| | |
|---|---|
| Moon | 2026 |
| Interstellar | 2028 |
| Mars | 2030 |

Please submit your content !

# Sixth Principle



## Build Global Eco - System

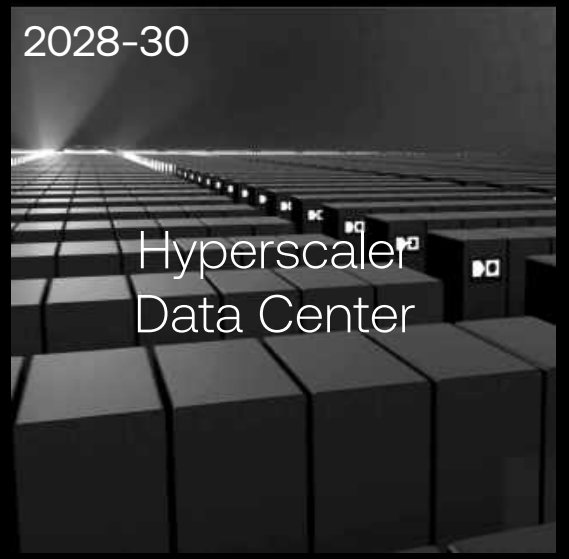
*Image Credit: NASA/Reid Wiseman*

# Development Roadmap from Demo to Hyperscaler Deployment


**Demo Systems**
1 PB/rack
100 MB/s
<90 sec to first byte


**On-Prem Systems**
5 PB/rack
500 MB/s
<30 sec to first byte

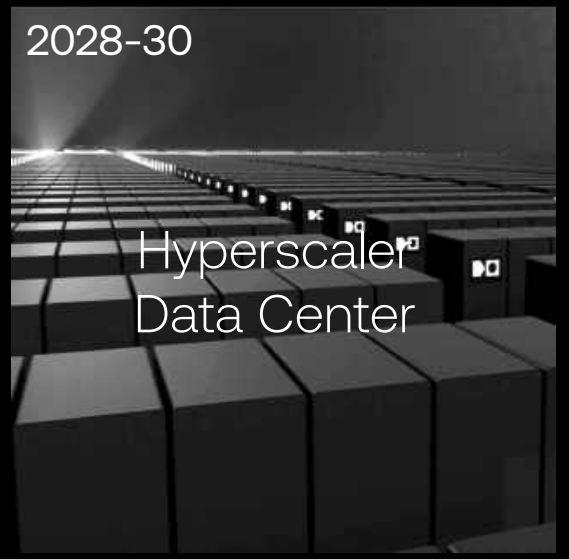

**Cloud Systems**
10-30 PB/rack
1+ GB/s
<15 sec to first byte




**Hyperscaler Systems**
60-100 PB/rack
2+ GB/s
<10 sec to first byte

# Initial positive response from all approached potential partners




## Sourcing Partners

Texas Instruments · CORNING · Sony DADC · intel

## Archive Partners

CERN · LIBRARY OF CONGRESS · piql · IRON MOUNTAIN

## Platform Partners

Hewlett Packard Enterprise · IBM · DELL · Western Digital · ORACLE

## Cloud Provider

aws · Azure · Meta · Google Cloud

# Proposal: New ”Cold data storage eco-system” would enable multi-sourcing supply chain through potential partner network


Multi-sourcing supply chain

| Substrate | Coating | Laser | Writing | Robotic | Reading | Decoding |
|---|---|---|---|---|---|---|
| Corning | Sony DADC | LightCon | Texas Instr. | BDT | Zeiss | Intel |
| Schott | Corning | Trumpf | IMS | Quantum | Nikon | AMD |
| NEG | AGC | Coherent | Zeiss | Spectra | Mitutoyo | Nvidia |
| AGC | Von Ardenne | EdgeWave | Intel | Logic | Edmund | Ampere |

# Cerabyte is seeking test & product development partners


Pilot Projects


Production Ramp-up


Volume Production


High-volume Production

# Cerabyte Management Team

Two generations creating a new standard for cold data storage

# cerabyte

## Store all data forever

Christian Pflaum, CEO & Founder
christian.pflaum@cerabyte.com

Ceramic Data Solution Holding GmbH
Rundfunkplatz 2 - Munich - Germany