



**MOON 2020-2030**

A new era of human and robotic exploration

# TOWARD ON-THE-MOON AND ON-PLANET 3D PRINTING

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# OUTLINE



- MOTIVATION - LIVING WITH LIMITED RESSOURCES
- AVAILABLE TECHNOLOGIES - HERITAGE
- FUTURE TECHNOLOGIES
- CONCLUSION - PROSPECTIVE

Additive Manufacturing / 3D Printing

Engineering Polymers

Material scarcity

Automation

Human Exploration Technologies

# MOTIVATION - LIVING WITH LIMITED RESOURCES



## FROM CLOSE SYSTEM

- DEPENDENCE ON CARGO
- TRANSPORTATION COST
- HABITAT MAINTENANCE

## TO EXPANDING SYSTEM

- INCREASE AUTONOMY
- MINIMIZE LOGISTIC NEEDS
- DIFFERENT CONCEPTS

HUMAN EXPLORATION / SETTLEMENT / EXPANSION

# MOTIVATION - MANUFACTURING NEEDS



## NEED FOR MULTI PURPOSE MANUFACTURING TOOL

- GENERAL MAINTENANCE CONCEPT
  - Less exchange with spare parts from ground
  - Enable versatile in-situ repair
- MANUFACTURING FOR EXPANSION

## ADDITIVE MANUFACTURING / 3D PRINTING

## NEED FOR RAW MATERIALS

- MINIMIZE MATERIAL SCARCITY
  - Use of local resources / Harvesting technologies
- OPTIMIZE USE OF IMPORTED RESOURCE
  - Packing density / High functionality
  - Full recycling / Zero waste

## THERMOPLASTIC / METAL / REGOLITH

## HERITAGE FROM ISS ENVIRONNEMENT

- LIVING IN CLOSE SYSTEM
  - Minimize waste
  - Optimize resources
  - Air and water recycling
  - Minimize / Optimize logistic needs
- NEW MAINTENANCE CONCEPT FOR EXPLORATION
  - No ORU replacement from ground stock

MATERIAL SCARCITY

RECYCLING

MAINTENANCE STRATEGIES



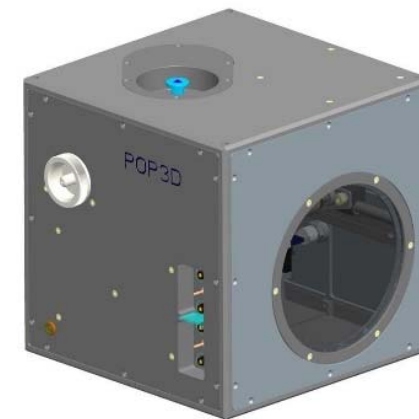
## 3D PRINTING ON ISS

- **Zero-Gravity 3D Printer**
  - **Made In Space/NASA**
  - Microgravity Science Glovebox – ABS
  - Numerous parts already printed
- **Portable Onboard Printer 3D (POP3D)**
  - **Thales Alenia Space/ASI**
  - Columbus rack - PLA



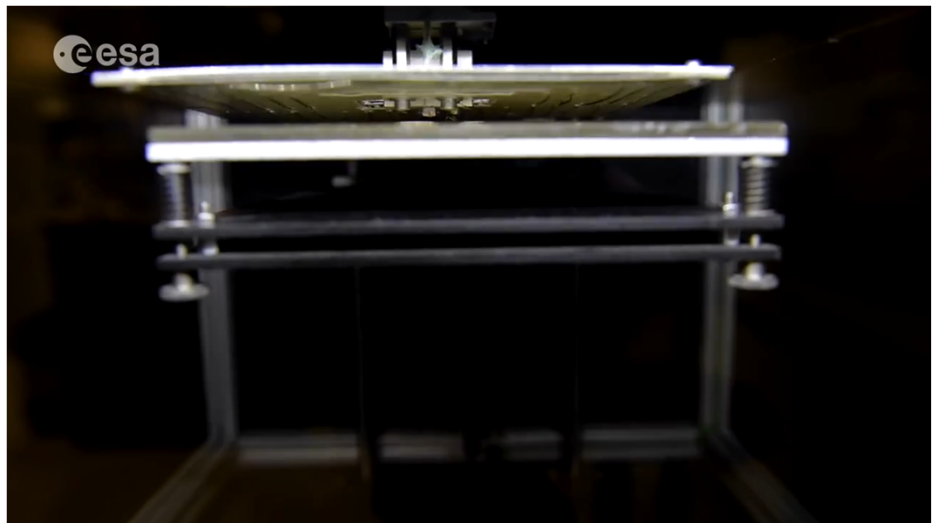
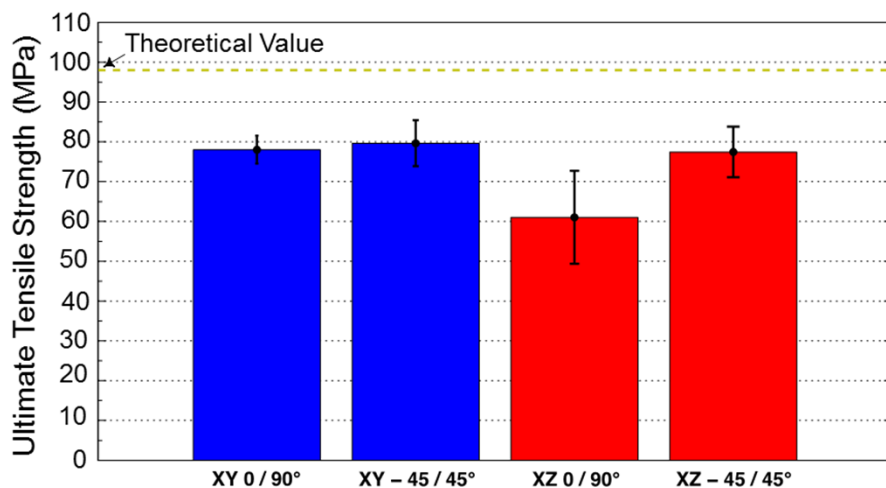
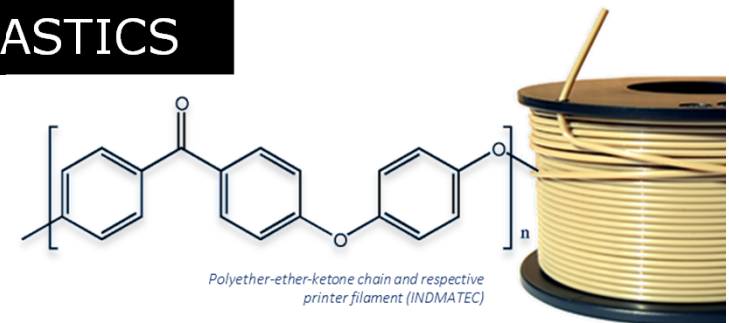
THERMOPLASTIC

SMALL PARTS



## 3D PRINTING WITH ENGINEERING THERMOPLASTICS

- Poly(ether ether ketone) - PEEK
- Thermal stability:  $T_m = 343^\circ\text{C}$
- Mechanical Performance:  $\sigma_{\text{tensile}} = 100 \text{ Mpa}$ ,  $E = 3.8 \text{ GPa}$



## THERMOPLASTICS STRUCTURAL PROPERTIES

## IN ORBIT 3D PRINTING

- **ESA - TRP project MELT:**
  - Breadboard development for in-orbit demonstration of additive layer manufacturing technologies
  - OHB/Active Space Technology/BEEVERYCREATIVE
  - Zero G - Engineering thermoplastics - High aspect ratio
  - Running phase: 3<sup>rd</sup> Q-2015 to 4<sup>th</sup> Q-2017
- **POSTER from Anna Dauriskikh et al:**
  - Manufacturing of experimental layer technology: melt project as building block for large structure manufacturing in-situ

## THERMOPLASTICS AND STRUCTURES





## ESA FUTURE ACTIVITIES REGARDING ADDITIVE MANUFACTURING

### POLYMERS

- High volume additive manufacturing
- Recycling and direct manufacturing
- Development of multifunctional engineering thermoplastics
  - Electrical conduction – Piezoelectric – Self-healing – Energy harvesting

### METAL

- ITT - ISS TECHNOLOGY DEMONSTRATOR - Development of a metal 3D printer demonstrator at the ISS

### ON-THE-MOON

- GSP - Conceiving a lunar base using 3D printing technologies
  - In-Situ Resources Utilization

# FUTURE TECHNOLOGIES



## ROBOTISATION – FULL AUTOMATION – UP SCALING

- BIG STRUCTURE
- INTELLIGENT DESIGN



## SETTELMENT AND EXPANSION



MX3D

**FUTURE ?**



## ON-THE-MOON AND ON-PLANET 3D PRINTING

**MATERIALS**

**RECYCLING**

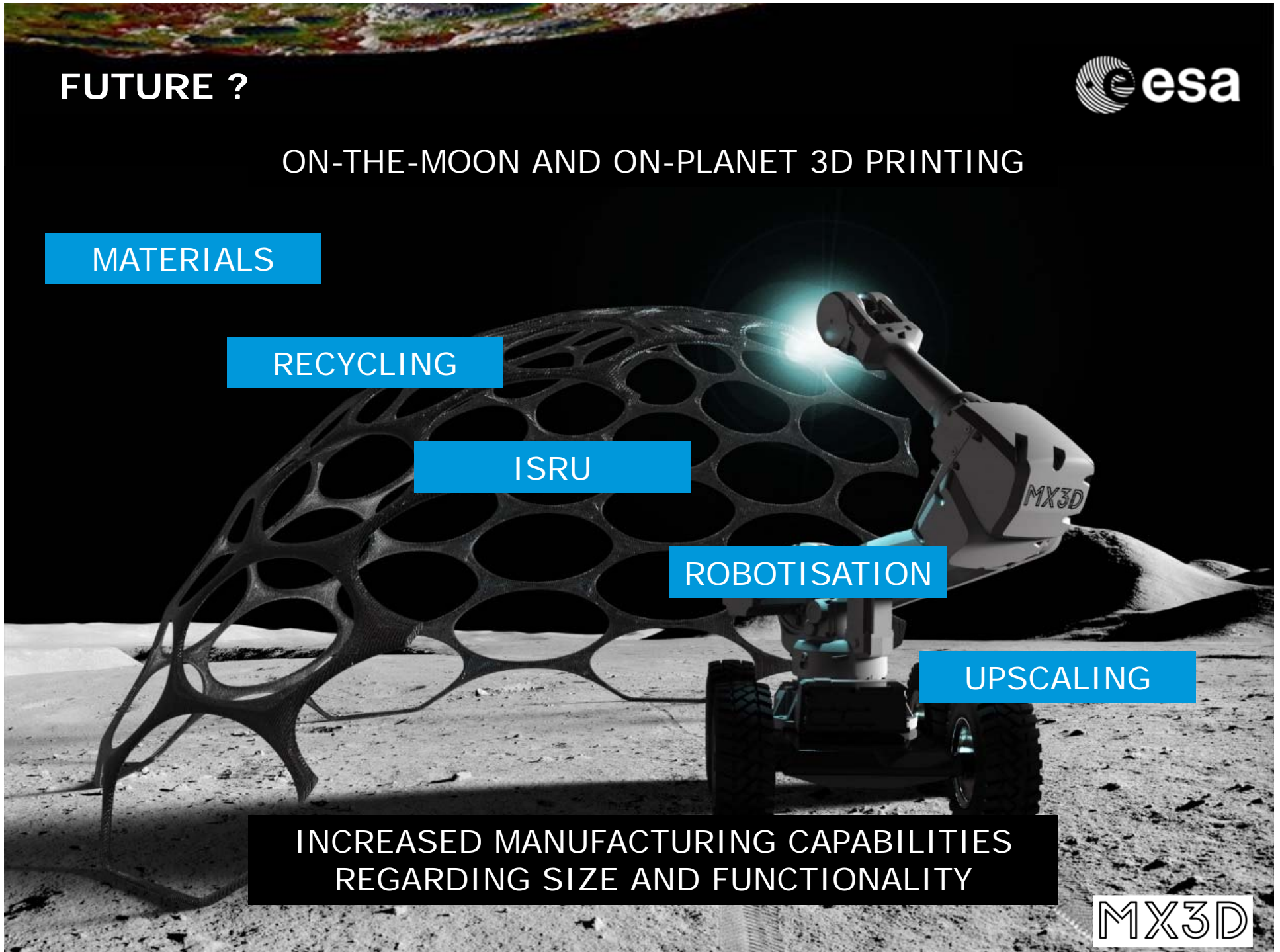
**ISRU**

**ROBOTISATION**

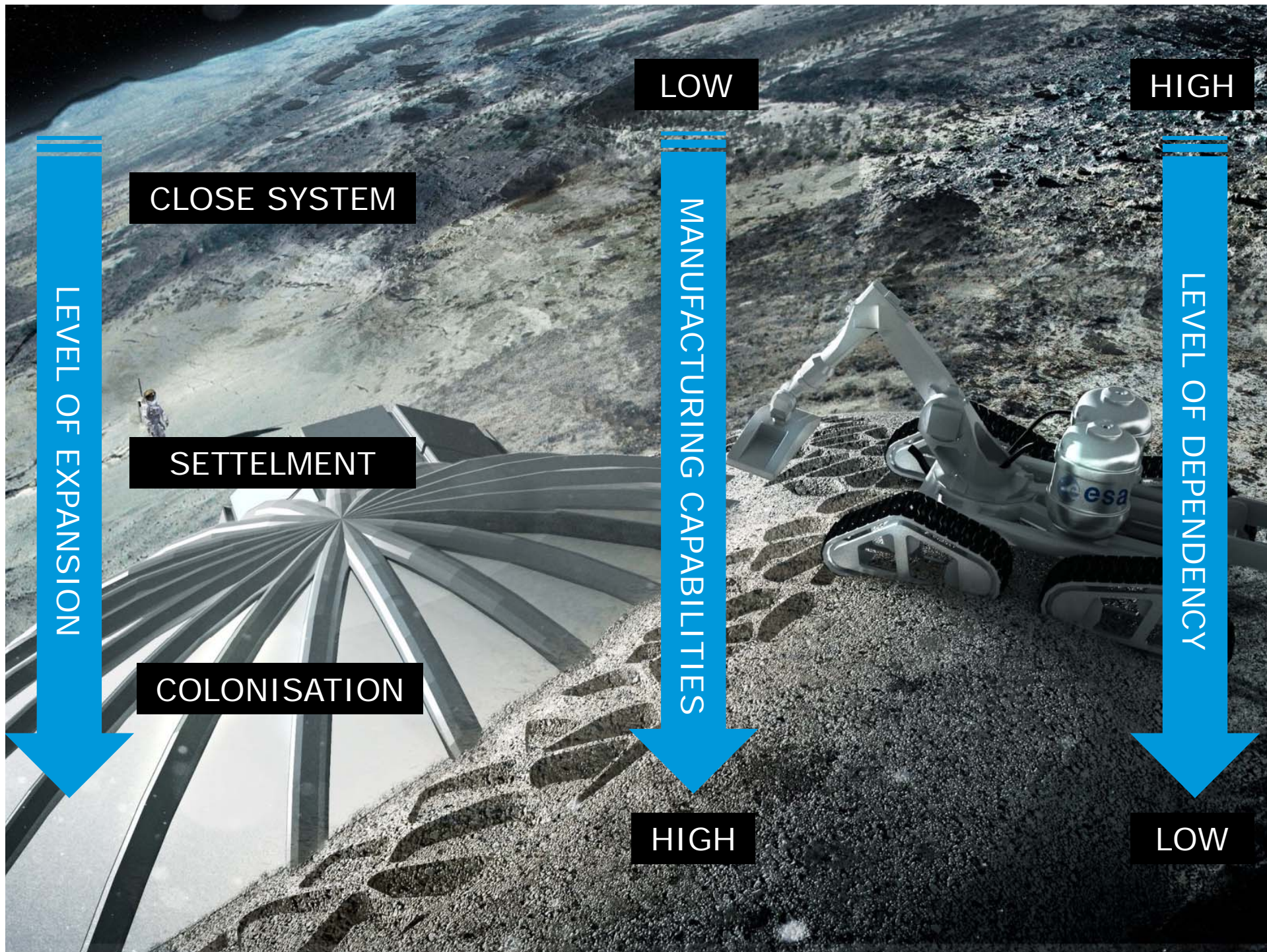
**UPSCALING**

**INCREASED MANUFACTURING CAPABILITIES  
REGARDING SIZE AND FUNCTIONALITY**

**MX3D**









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**MX3D**

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**THANK YOU FOR YOUR ATTENTION**