Materials for Space – Challenges & Opportunities

Dr Neelam Mughal – Advanced Materials

Innovate UK KTN

In partnership with: dstl

The Science Inside

About Us

Innovate UK KTN exists to connect innovators with new partners and new opportunities beyond their existing thinking – accelerating ambitious ideas into real-world solutions.

The Science Inside

Advanced Materials Programme

Dstl new S&T Portfolio

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Emphasis on **Generation After Next** S&T

- **Advanced Materials**
- AI
- CBR Defence
- Future Workforce & Trg
- Human Perf & Protection
- Comms & Networks
- Future Kinetic Effects & Wpns
- Autonomy
- Influence & Command
- Electromagnetic Activities
- Cyber Security
- Defence S&T Futures
- Future Sensing

Emphasis on S&T **Services** to wider MOD

- Support and Sustainability
- Support to Operations & Crisis
- High Level Decision Spt

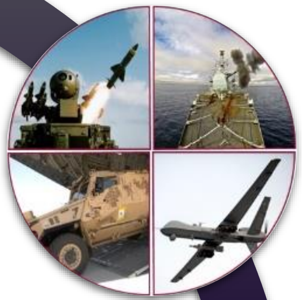
Emphasis on **Accelerating Next Generation** S&T

- Maritime Systems
- Deterrent and Sub Sys
- Specialist Systems
- Space Systems
- Security Systems
- Air Systems
- Land Systems
- Missile Defence

Focused

- Hypersonics
- Engineering Bio
- PULSAR
- Human Augmentation
- Crime & Policing

https://www.gov.uk/government/publications/defence-science-and-technology-programmes-and-projects/ministry-of-defences-science-and-technology-portfolio



Advanced Materials Programme (AMP)

Purpose of roadmap

- Work with the community to identify materials challenges, technology gaps & opportunities
- Inform Dstl’s Materials for Space Science & Technology Research priorities

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Deep dive – Sustainability

Space is becoming increasingly congested

- Space junk clutters the low earth orbit space environment, & poses a hazard to future MOD capabilities
- Defence must be a responsible space user
- Taxonomy – sustainability is not just space junk

How can advanced materials & processes make more sustainable space assets?

- 'Green' fuels for launch vehicles and propulsion
- Demisable materials / controlled break-up
- Re-use of space assets e.g. refuelling, repair, recycling
- Deorbiting technologies / novel solutions to trigger orbital decay
- Space debris removal strategies

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Barriers to Innovation

Demisable Materials

- Testing and validation is a complex process.
- Changing the types of material used may lead to an increasing amount of CO_2 in the atmosphere depending on the material choice.
- Environmental impact and toxicity.

Space Debris

- Orbital debris removal is currently very expensive and still in the trial phase
- Requires international cooperation, and global regulations to mitigate space debris.
- Some companies feel that there is a lack of funding available and therefore feel there is no incentive to reduce debris.
- There were issues identified regarding the type of material that could reduce debris or could break up and cause more debris.

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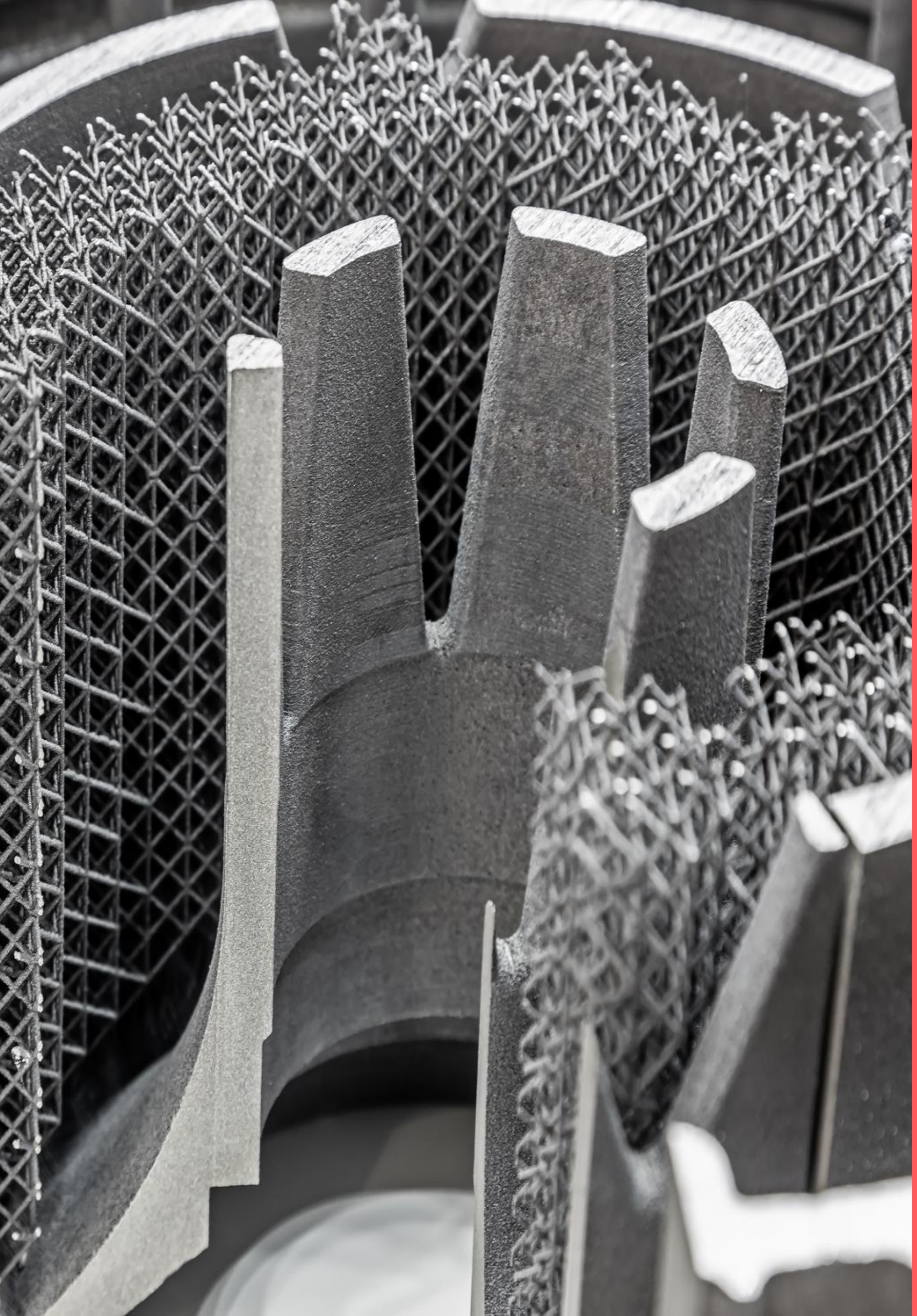
Opportunities for Materials Innovation

•Develop demisable alternatives for critical materials used in space such as ceramics, stainless steel, beryllium, titanium, tungsten, invar, and silicon carbide. These alternatives should be able to meet the thermal stability and optical requirements for payloads.

•Explore the potential of biomaterials and structures in space applications. Develop bio-derived, bio-mimetic, and biocomposite materials that can withstand the harsh space environment and be used for spacecraft, radiation shielding, demisable components etc.

•Novel materials for active debris removal strategies for example high-temperature superconducting magnets, nets/harpoons, and electrodynamic tethers.

Novel materials of interest: aluminium-lithium alloys, recyclable composites, biomaterials, high-temperature superconducting materials, ceramics.



Deep dive – Lightweight Materials & Structures

- The cost per kilo of launch is high, although this is falling
- Fundamental limit imposed by size and mass that can be launched in fairing

MOD would look to exploit developments in lightweight structures to make space assets more capable.

Some examples include (but not limited to!):

- **Large** apertures for high resolution Intelligence, Surveillance Reconnaissance (ISR) → large deployable structures, formation flying cubesats, in-orbit assembly
- **Lightweight protection** of space assets e.g. integrating radiation shielding, micrometeoroid shielding → multifunctional structures

Multifunctionality can reduce system mass

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Barriers to Innovation

Heritage material reliance

- Aluminium the best compromise of properties for many space applications therefore a barrier to innovation is developing a material that can go beyond all the characteristics of aluminium e.g. higher strength-to-weight ratio, higher strength and stiffness, performance at extremely high temperatures (re-entry). Titanium addresses these concerns (apart from demisability).

Composites

- Outgassing testing is a crucial first step for materials for space testing - there are a small number of facilities that can do these measurements, that some companies find difficult to access: TS-Space Systems (ECSS standards), UCL, RAL Space, University of Leicester.

Interfacial Bonding & Joining

- Achieving reliable and durable bonds between different materials or joining dissimilar materials is critical for constructing lightweight structures. The compatibility of materials and the development of effective bonding techniques, such as adhesive bonding, welding, or additive manufacturing processes, can pose challenges.

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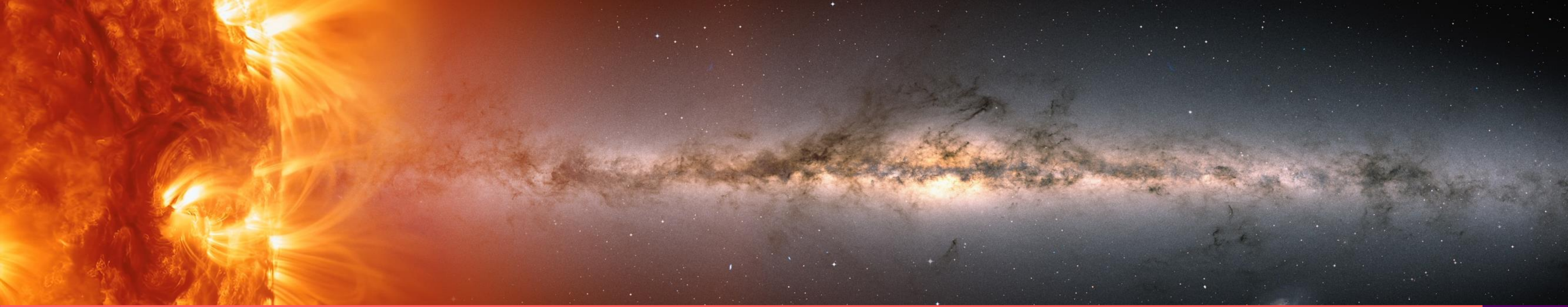
Opportunities for Innovation

•Develop novel materials that can be optimised by design for lightweighting in space applications, including deployable structures, additive manufacturing materials, metamaterials and metallic foams.

•Develop lightweight materials that can be used to reduce the weight of radiation shielding cases for electronics in space. These materials should be able to withstand the space environment and protect electronics from radiation.

•Developing dual-use materials and coatings that can provide impact resistance against man-made threats as well as micrometeoroid/space debris. These materials should be able to provide protection to both manned and unmanned space systems.

Novel materials of interest: Self-repairing materials, metamaterials, knitted materials, shape memory materials, composites, polymers, 3D printed structures



Deep dive – Materials to Survive the Natural Space Environment

Space is a challenging environment

- Huge acoustic and vibrational loads on launch
- Impact of vacuum, radiation, atomic oxygen, thermal cycling on orbit

Material selection is critical & can unlock improvements in efficiency, performance & life

- Coatings & atomic oxygen (AO) protection strategies
- Damage tolerant and self-healing material
- Radiation hardening / shielding (e.g. Van Allen Belts)
- Manmade threats Challenges_Security_Space_2022.pdf (dia.mil)

MOD requires assurance that materials / components will last long term & performance maintained

- What is the impact of the space environment on material properties and how does it impact the performance?

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Barriers to Innovation

ATOX testing

- ESTEC TEC-QEE Section operates an atomic oxygen beam source in the Materials and Electrical Components Laboratory, which is the only one of its kind in Europe. Due to the complexity of the facility and the relatively high operating cost, access to the facility is usually only affordable for the larger industrial primes and national agencies.

Long Development Cycles

- Developing new materials for space applications often involves extensive research, iterative design, prototyping, and testing cycles. Time to market for some missions can be long (>5 years), in the case of constellations, agile manufacturing would be required. The lengthy development cycles can delay the adoption of new materials in space missions.

Lack of Spaceflight Heritage

Reluctance from space agencies and mission developers to adopt new materials without a demonstrated spaceflight heritage can slow down the acceptance and adoption of innovative materials. The qualification process and gaining flight heritage for new materials require significant time and investment.

Defined Challenge Requirements

Understanding specific materials challenges and scope of required solution - If companies were able to work to a defined set of requirements this could be a quicker way to design, develop and qualify a new material for space.

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Opportunities for Innovation

•Develop materials with high thermal conductivity or tailorable CTE that can be used in space systems and structures. These materials should be able to efficiently transfer heat and withstand the thermal stresses of the space environment.

•Investigate metallic glass structures and components that can be used in space and defence applications. Study the aging and degradation performance of these materials and develop life extension methods to ensure their longevity in space.

•Develop materials and coatings that can resist AO, UV, and other forms of radiation in the space environment. These materials should be able to withstand the harsh space environment and provide protection to space systems and structures.

Novel materials of interest: Metal Matrix Ceramics, metamaterials, high entropy alloys, bulk metallic glasses, polymeric materials, diamond, graphene.

Opportunities for Innovation

Theme	Key Materials	
	Traditional	Novel
Radiation tolerant materials	Aluminium, beryllium, titanium and tungsten alloys	High entropy alloys, nuclear graphite, bismuthene, diamond, silicon carbide, fused silica
Atomic oxygen resistant materials	Gold coated foils	Novel polymer formulations for polymer composites
Shielding from micrometeoroid and debris impact	Whipple shield, aerogels	MMCs, ceramics, silicon doped boron carbide, SynBio materials
Low / tailorable CTE	Ceramics, silicon, Invar-36, glasses	High entropy oxides, aluminium-silicon alloys, MMCs, silicon carbide, beta titanium-alloys, thermoset composites
Materials for thermal management	Multilayer insulation, aerogels	Diamond, graphene, polymers, metamaterials, ceramics, high entropy alloys
Low outgassing materials	Aluminium, ceramics	MMCs, polymers, plastics, composites
Protective coatings	Ceramics, metal oxides, diamond, metamaterials	

Current Opportunities

AIRBUS

Automated Potting Equipment (APE) – Installation of Insert Fixtures on Spacecraft

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The iX challenge competition, delivered by Innovate UK KTN, is supporting Airbus to identify innovative partners that have the capability to manufacture an automated solution for installing insert fixings to Satellites. The business(es) with the most promising solution(s), as selected by the challenge owner, may be given a commercial opportunity to deliver their solution and receive support from Innovate UK KTN and the wider Innovate UK network.

https://www.ktninnovationexchange.co.uk/challenges/255/automated_potting_equipment_ape_installation

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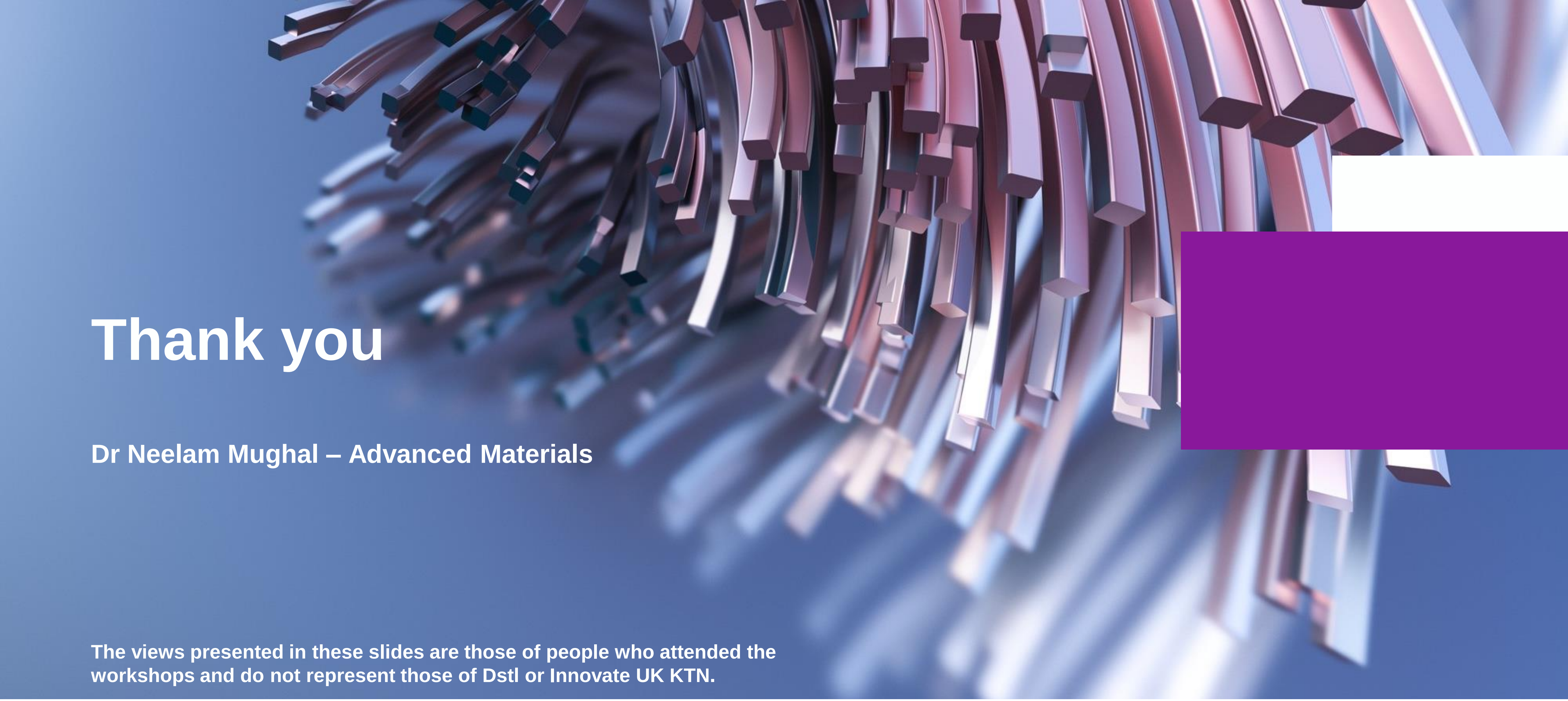

Thank you

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The views presented in these slides are those of people who attended the workshops and do not represent those of Dstl or Innovate UK KTN.

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