Advanced Materials & In-Orbit Manufacturing Accelerator

Webinar Session Notes:

Commercial Microgravity – State of Play and Future Direction for Advanced Materials and Manufacturing

A high-level forum bringing together leaders from across the ecosystem to explore the present landscape and future trajectory of commercial microgravity R&D—covering supply chains, enabling technologies, and the innovation pipeline for advanced materials and manufacturing.

Table of Contents

Session One: Trends and Emerging Dynamics

How demand, infrastructure, and platform usage are evolving — and where opportunity zones are emerging.

1.1 Speakers

- Moderator: Hamid Soorghali – Industry Strategist, Catapult
- Rose Hernandez – Science Program Director, Advanced Materials Manufacturing, ISS National Lab
- Ken Savin – Chief Scientist, Redwire Space
- Erik Kulu – Founder, Factories in Space

1.2 Brief Context

This opening session set the baseline for the entire webinar series, exploring how microgravity R&D is shifting toward becoming an active commercial marketplace.

Moderated by Hamid Soorghali (Satellite Applications Catapult), the panellist discussed demand dynamic and trends, ecosystem, and enabling infrastructure needed for scaling.

Speakers noted that while interest and proposal volumes are at record highs, the ability to convert demand into commercially repeatable outcomes depends on maturing platforms, aligning economics, and addressing the TRL gap.

The discussion focused on shifts in demand for microgravity-based advanced materials R&D, the role of traditional and emerging players, and the enabling infrastructure Additional context from the discussion reinforced that this is not a short-term spike but a sustained shift in the technology and market landscape.

Speakers noted that agency calls for proposals are consistently oversubscribed, signalling that research pipelines are expanding faster than available infrastructure.

Rose Hernandez emphasised that demand in area of advanced materials companies is being driven by major trends and shifts:

The semiconductor sector approaching CMOS scaling limits.

The rise of the quantum technology era which requires new material platforms.

Erik Kulu cautioned that despite growth in proposals and infrastructure investment, there is still no “killer application” with sustained repeat production.

Ken Savin agreed with this realism but stressed that the underlying IP generation and process innovation in space are building the initial foundation for future commercial

1.3 Key Points Discussed

a. *Demand Growth, Market Diversification, and TRL Gaps*

- **Demand at record levels.** Rose Hernandez highlighted that "the demand is so high we cannot keep up." This is visible in area of advanced materials, where companies are seeking microgravity's benefits for structural control, defect reduction, and novel phase formation.
- NASA's In Space Production Applications (InSPA) awards is highly oversubscribed, and several different programme windows have experienced over-demand, indicating a broad structural shift in industry interest.
  - The ISS National Lab has launched an accelerator program [Orbital Edge Accelerator programme] for startups to widen access.
- Growth areas: Biotech, pharmaceuticals, regenerative medicine continue to dominate, but optical fibres (ZBLAN), semiconductor materials, and materials for quantum technologies are seeing sharp interest.
  - This diversification of growth areas reflects greater private sector confidence in operational readiness, even though the platforms are still being developed and currently optimised for research more than production.
- Quantum and semiconductor can be major macro trend drivers for microgravity demand:
  - "We're moving towards the quantum era… we are in the middle of this semiconductor bottleneck… we have reached the limits of traditional CMOS."
  - Quantum technology driving demand for new materials with controlled structural precision.
- Panellists agreed that projects often attempt to leap from TRL 3 to TRL 6–7 without intermediate demonstration stages.
  - This gap is a recurring investor concern and a barrier to commercial adoption.
- Rose noted: Butler University's database of 160 semiconductor compounds tested in microgravity—80% of which showed improvement—underscores untapped potential but also highlights the need for systematic follow-on experiments.

- Additional note: This was cited as an example of valuable but under-leveraged knowledge—clear performance benefits are documented but repeat flights and scaled production trials remain limited.

b. *Commercial Reality vs. Optimism*

Few commercial products to date – Erik Kulu noted that only two confirmed products have sold commercially from microgravity research

- Optical crystal production (Redwire, ≈2 g sold for $4,000 in 2002).
- Latex spheres from Shuttle Challenger-era missions in the 1980s.

- Erik notes that a market inflection will come when one product achieves repeatable production, which will enable process optimisation and cost-down—creating a "flywheel" for scalable commercial cycle in in-space manufacturing
- IP over physical products in early stages – Ken Savin reframed expectations by noting that early outputs should be seen as IP-generating steps rather than products for mass production. He used the pharmaceutical industry analogy:
  - "Companies will make money from intellectual property, not manufacturing per se."
- Ken predicted that in the medium-term outlook commercially significant pharmaceutical crystals will likely emerge in the next few years, but early efforts will "flounder" before a scalable model is proven.
  - Other panellists pointed out that the sector should anticipate a trial-and-error period before a stable market leader emerges.
  - Early attempts may still produce critical technical or IP assets even if initial commercial runs fail to scale immediately.

c. *3. Enabling Technologies, Infrastructure, and Economic Constraints*

- Logistics economics and cost barriers – Ken quantified ISS logistics costs at $20–25k/kg, restricting commercial viability to products with exceptional market value or performance leverage.
  - Very few materials can sustain these economics unless they have extremely high market value or performance advantage.
- Candidate product classes:
  - Semiconductor precursors or specialty crystals with significant downstream leverage.

- High-value nanomaterials (e.g., gold nanospheres—a multi-billion-dollar market with low mass-per-unit).
- High-stability pharmaceutical crystal forms.

- Enabling technology pipeline: Redwire continues to develop enabling hardware (manufacturing units, reactor modules) both for its own R&D portfolio and as infrastructure for the wider ecosystem.
- Platform readiness: Rose Hernandez stressed that the ISS is a research platform, not a dedicated production facility.
    - Future commercial platforms (free-flyers, private stations) are expected to fill this role but are not yet operational.
- Additional note: Several speakers described modular hardware strategies—standardising rack-size production units and payload formats to reduce experiment adaptation times and enable repeatable integration cycles across different missions.

d. Sector Maturation, and Industry Participation

- Non-public data and hidden progress: Rose explained that much commercial work is not published:
    - “We see data you will not see… companies choose who they show the data to.”
    - Proprietary results already influence government partnerships and private follow-on investment.
- Proprietary results are already influencing government partnerships and private follow-on investment.
- Perception vs. process: Rose Hernandez cautioned against viewing the current churn as dysfunction:
    - “It has to happen this way… infrastructure is being built at the same time as science is being translated… it will fall into place.”
- Funding asymmetry: Erik explained that his database shows 50+ re-entry vehicle projects and several $1B+ commercial station efforts are well-funded, but most in-space manufacturing companies remain idea-stage or lightly funded.
    - This imbalance could limit the near-term commercial pipeline.
- Industry engagement timing: All panellists stressed the importance of early industry engagement to align technical design with commercial requirements.

- Current engagement is often too late, resulting in designs mismatched to market needs.
- Additional note: A key risk identified is timing misalignment between industry product cycles and space programme schedules.

- Delays of several years between proof-of-concept and follow-on opportunities can result in loss of market windows or customer interest.

1.4 Key Takeaways

a. *Current State of Play*

- Demand is high, but platform availability and integration bottlenecks are limiting throughput.
- TRL progression gaps and long timeframes remain obstacles; even promising projects face a multi-year path to market. Projects continue to attempt jumps from TRL 3 to TRL 6–7 without intermediate maturity steps, creating risk for investors and industrial users.
- Commercial outputs are limited to IP generation and proof-of-concept demonstrations; sustained product sales have not yet occurred.
- Infrastructure development is well ahead of manufacturing maturity: capsules and stations are funded, but product-focused ventures are thinly capitalised.
- Platform constrains remain. The ISS remains the primary research platform but is not optimised for continuous production, limiting throughput and scheduling flexibility.
- Economic limits – Logistics costs ($20–25k/kg) restrict viable products to very high value or high leverage materials.

b. *Future Outlook & Direction*

- The first repeatable, profitable product (optical fibre, nanomaterials, pharmaceutical crystals) will be the inflection point for market acceleration.
- Public–private accelerators (e.g., InSPA, ISSNL Accelerator, ESA BSGN) will help bridge TRL and market gaps, especially for startups.
- Economic modelling—transparent, peer-reviewed, and inclusive of full logistics costs—will be critical to validate commercial viability, market confidence, and support investment cases.
- Platform diversification (private stations, free-flyers) will reduce scheduling bottlenecks and align better with commercial timelines.

- Over the next 2–3 years, expect ISM for Earth markets (high-value, low-mass products) to run in parallel with ISM for space-based applications (e.g., power systems, structural components), gradually expanding demand.

Additional reading materials:

- **Report** – ISS National Lab Annual Report for 2024- ISS National Lab
- **Publication** – 2024 Industry Survey, Trends, Economics and Enablers, Erik Kulu Factories in Space, Nanosats Database, NewSpace Index
- **Presentation** – Microgravity Manufacturing for Terrestrial Applications What's Different Now? November 2024
- **Publication** – Semiconductor Manufacturing in Low-Earth Orbit for Terrestrial Use, Authors Jessica Jane Frick, Erik Kulu, Gary Rodrigue, Curtis Hill, and Debbie G. Senesky
- **Presentation** – A presentation by Redwire on their past, ongoing and planned projects

Session Two: Research Translation into Commercial Ventures

Mechanisms and bottlenecks in translating institutional research into commercially viable microgravity ventures

2.1 Speakers

- Phil Carvil, Head of Clusters, STFC, former President of ELGRA
- Advenit Makaya – Advanced Manufacturing Engineer
- Vito Di Pietro – Technology Broker, TWI / ESA Tech Broker Network
- Gilles Billet – Researcher and lecturer, University of Glasgow

2.2 Brief Context

This session explored the pathways by which microgravity research transitions from academic or agency-funded projects into commercially viable ventures. Moderated by Phil Carvil, the panel examined mechanisms supporting translation, recurring barriers that slow it, and adjustments to improve industrial adoption.

Speakers stressed that successful translation requires continuity across the full TRL spectrum, hardware that is ready for commercial timelines, and early industry engagement to align design with market needs. Examples included additive manufacturing demonstrations on ISS, ESA's Advanced Manufacturing Initiative, and technology transfers from regulated sectors such as nuclear robotics.

- Makaya stressed that **continuity across the full TRL spectrum** is critical: research often stalls after a single flight demonstration because follow-on funding or hardware access is missing. *"Even the best experiments risk becoming one-off successes without sustained access to flight."*
- Speakers highlighted that **hardware readiness** must be aligned with **commercial timelines**, and **industry needs to be engaged early enough** so that product and process development meet actual market demand.
- Examples ranged from **polymer and metal printing on the ISS** to ESA's **Advanced Manufacturing Initiative**, as well as cross-sector technology transfer from **nuclear robotics** and **fusion operations**, which provide analogues for working in remote, high-complexity, safety-critical environments.
- All panellists pointed to **gaps in sustained demonstration flights** and **constraints within academia**—such as short-term funding and misaligned incentives—that limit spinout creation.

2.3 Key Points Discussed

a. Breadth of R&D and TRL Progression

- Microgravity-enabled R&D spans **multiple domains**—advanced alloys, ceramics, polymers, composites, and embedded electronic systems—but commercial translation often stalls **earlier than expected**.
- Academic TRL bottlenecks – Billet highlighted that many academic teams face a **funding "valley" between TRL 4 and TRL 6**, when technical feasibility is proven but **industrial demand and certification pathways remain uncertain**. This gap often forces projects to pause, dissipating momentum.
  - It was added that current funding frameworks often expect **TRL jumps from 3 directly to 6**, bypassing incremental in-space tests that would build confidence and de-risk later stages. This approach creates **technical risk for investors** and undermines commercial confidence.
- Makaya explained ESA's *Advanced Manufacturing Initiative*, which selects technologies with a **step change in performance, lead-time reduction, or design freedom**.
  - Additive manufacturing is a primary focus due to its potential for **mass reduction, embedded functionality**, and **complex geometries** not achievable through traditional manufacturing.

- The **ISS metal printing demonstration in 2024** represents a significant advance beyond earlier polymer-based experiments, enabling work with **metals, ceramics, and integrated electronics**.
    - Makaya noted that while this opens broader application potential, it also raises **qualification, repeatability, and inspection** challenges that must be solved before industrial adoption.
- Access to early flights – Some SMEs and university groups secure early in orbit demonstrations through ESA's ScaleUp programme and Marketplace platform, bypassing slower research cycles.

b. For-Space vs. In-Space Manufacturing

- For-space manufacturing (Earth-based production of spacecraft hardware) continues to mature.
    - Di Pietro noted that additive manufacturing remains more costly than conventional production, mainly due to extensive qualification testing. Reducing the cost and complexity of these campaigns is essential for AM to be competitive for flight hardware.
- **In-space manufacturing** focuses on producing components and materials directly in microgravity.
    - Makaya emphasised that the next step in this area is **expanding material diversity**, supported by **in-process monitoring and modelling** as post-flight laboratory validation is limited in scope and speed.
    - Makaya noted that **inspection integration** from the start is vital. Building trust in in-space production will depend on **standardised qualification frameworks** and **automated quality assurance systems** adapted from other industries.
    - Speakers referenced automated inspection rigs and diagnostic frameworks from fusion and nuclear sectors as strong analogues for monitoring in-space processes, as they share similar remoteness, limited intervention windows, and high safety standards.
    - Makya added that cross-sector capability transfer is active, pointing to robotics expertise from nuclear and fusion energy operations—which operate in remote, vacuum-compatible, and radiation-hardened conditions—as a ready model for autonomous space manufacturing systems.

c. *Industry Engagement and Market Alignment*

- **Industry evaluates microgravity ventures through three consistent filters:**
    a. **Process reliability** — whether it can be repeated under production conditions.
    b. **Certification pathway** — whether a clear, feasible route to qualification exists.
    c. **Market fit** — whether there is a defined customer application or sector demand.
- Speakers observed that industry engagement often comes **too late**, after research programmes have locked into technical designs and timelines that are **misaligned with market cycles**.
    - Early engagement allows **industry to shape design parameters** to meet operational and commercial needs.
- Di Pietro, speaking from the ESA Tech Broker perspective, stressed that **connecting research teams to integrators and commercial partners early** significantly improves translation success.
    - He noted that projects matched with the **right industrial partner at TRL 3–4** often reach demonstration faster than technically comparable projects that enter the market search later.
    - He emphasised that **market alignment is not automatic**: even promising technology can stall if it reaches the wrong industrial audience or if the timing doesn't align with sector procurement cycles.
    - Di Pietro noted that delays of 3–5 years between early demonstration and follow-on opportunities often lead private partners to disengage, especially in fast-moving technology markets where competitive advantage erodes quickly.

d. Academic Constraints and Spinout Formation

- University researchers increasingly aim to commercialise their research, but promotion metrics still reward publications in high-impact journals over translational outputs.
    - Billet remarked that until spinouts and IP generation are valued on par with publication, most academic work will not reach TRL 5–6.
- Short-term funding schemes, such as 9-month ESA de-risking contracts, limit the ability of academic teams to retain technical staff between project milestones.

- This disrupts continuity, as researchers often have to reassemble teams, retraining new hires at each phase.

- UK's Research Excellence Framework (REF) is shifting toward impact-oriented measures, which could improve incentives for translational space research.
- Long-term academic support, such as the Royal Academy of Engineering Chairs in Emerging Technologies, provides rare stability.
  - These 10-year grants allow sustained development of concepts and hardware to a point where spinouts become commercially credible.
- Additional expansion: Billet pointed out that niche microgravity hardware integration expertise is especially vulnerable to discontinuity — if key postdocs or engineers leave between contracts, years of tacit knowledge are lost, slowing translation.

e. Mechanisms Supporting Translation

- Additional expansion: Billet pointed out that niche microgravity hardware integration expertise is especially vulnerable to discontinuity — if key postdocs or engineers leave between contracts, years of tacit knowledge are lost, slowing translation.
- ESA's Marketplace and ScaleUp initiatives provide early commercial anchors for microgravity companies, enabling some to bypass slow traditional R&D cycles and reach demonstration readiness sooner.
- ESA's Business Applications and Space Solutions (BASS) funds incremental development from market research to early customer transactions.
- Makaya highlighted DcubeD (Germany) as a strong example: a polymer printing process developed at Munich University that progressed to in-orbit demonstration by combining flight heritage hardware with commercial co-funding through ESA programmes.
  - This reduced the need for a full qualification campaign and accelerated TRL progression.
- Di Pietro emphasised that ESA Tech Broker Network can shorten the path to demonstration by pairing innovations with existing industrial roadmaps rather than waiting for entirely new market creation.
  - He noted that some of the most successful transitions have come from adaptations of terrestrial industrial problems to space contexts, where a microgravity solution offers a performance advantage.

- Makaya emphasised that successful translation teams typically combine three elements:
    - Technical excellence (validated process or device).
    - Market insight (clear application and target customer).
    - Integration partnership (alignment with platform providers and launch access).

2.4 Key Takeaways

a. ***Current State of Play***

- Translation mechanisms (ESA Advanced Manufacturing, ScaleUp, Marketplace, BASS) exist but are unevenly accessible to academic researchers.
- TRL bottlenecks often occur earlier than TRL 6, with many academic projects stalling at TRL 3–4 due to lack of sustained demonstration and continuity funding.
- For-space manufacturing (Earth-based production) is advancing faster than in-space manufacturing, but both need cost and qualification process alignment to be commercially viable.
- Industry engagement timing remains a weak link; research often reaches technical maturity out of phase with market demand cycles.

b. ***Future Outlook & Direction***

- Standardised modular payloads and qualification frameworks can cut adaptation times and reduce barriers for academic and SME participation.
- Platform diversification (private stations, free-flyers) and earlier demonstration access will shorten the time from research to commercial adoption.
- Funding models need to evolve to support longer-duration, impact-driven research and TRL 3–5 continuity, avoiding dependence on short-term grants.
- Cross-sector partnerships (robotics, materials, automation from nuclear/fusion) can accelerate technology readiness and widen the industrial supplier base.
- The first repeatable in-space product with consistent production will mark a turning point, creating investor pull and establishing sustainable commercial markets.

Session Three: National & European Initiatives

3.1 Speakers

- Moderator: Mike Curtis-Rouse – Head of In-Orbit Servicing, Assembly, and Manufacturing (ISAM)
- Francesco Liucci – Innovation Management Officer, ESA ESTEC; Lead, BSGN Accelerators
- Carl Savage – Programme Manager, ESA BIC Harwell, STFC UKRI

3.2 Brief Context

This session examined how national and European institutional initiatives are shaping the commercial microgravity ecosystem. With the ISS approaching retirement in 2030 and private platforms in advanced development, Europe's coordinated strategy is positioned to help early-stage ventures transition into the new market environment.

The discussion focused on two ESA-managed frameworks:

1. ESA Business Incubation Centre (BIC) – supporting early-stage ventures at TRL 3–4, with emphasis on building a viable business case, investor readiness, and MVP development.
2. ESA BSGN Industrial Accelerator – providing late-stage co-funding and market access for companies ready to demonstrate their technology in microgravity, often at TRL 5–7.

These programmes are time-sensitive. The institutional push to mature ventures must coincide with the final operational years of the ISS and the opening of capacity on commercial free-flyers and private stations.

Speakers stressed that Europe's dual-track approach—early-stage incubation through ESA BIC, followed by demonstration support through BSGN—is rare among space agencies. This continuity of support is critical for the microgravity economy to move from project-based activity to sustained market growth.

3.3 Key Points Discussed

a. *Convincing Investors: From "Expensive Lab Ride" to Market Opportunity*

- Francesco outlined the central challenge of positioning microgravity for investors: shifting from a perception of paying for expensive laboratory experiments to buying into an industrial production environment.

  - ISS has produced a strong scientific track record in advanced materials, life sciences, and biomanufacturing. However, its model has been primarily retrofit to accommodate experiments rather than built for repeatable production at commercial cadence.
- Investor confidence requires:
  - A documented base of results that demonstrates unique value.
  - A credible path to repeatability and scale beyond single-use payloads.
- Francesco emphasised that as Europe transitions from the ISS to commercial platforms, accelerators like BSGN must identify terrestrial bottlenecks (e.g., semiconductor defect control, biopharmaceutical crystal consistency) that microgravity can address with measurable advantage.
- Carl reinforced that for investors, the key is to clearly define the market problem and its size.
  - Microgravity manufacturing is compelling when the performance or economic advantage cannot be matched by terrestrial methods.
  - He cautioned against overhyping near-term potential (which can lead to market disillusionment) or pushing payoffs too far out (which can cause investor disengagement).

b. ESA BIC: Pan-European Early-Stage Support

- Carl described the ESA BIC network as a Pan-European programme with local delivery, tailored to national priorities.
  - Example: ESA BIC Harwell in the UK is managed by STFC, integrating national innovation policy with ESA technical resources.
- Support package typically includes:
  - Non-dilutive grant funding (~€60k standard model).
  - Business coaching, IP advisory, technical mentoring, and investor preparation.
  - Facility access at national labs (e.g., RAL Space in the UK) to support technical validation.
- Programme objectives: advance companies from TRL 3 (concept validation) to MVP readiness within 18–24 months.

- Carl stressed that the ESA BIC is not a purely technical programme—its purpose is to build an investable business around the technology.
- By the end of the programme, companies should have a defined market path, a validated product proposition, and be ready for next-stage funding or demonstration
- Boost funding—recently introduced in the UK ESA BIC model—significantly expands the level of support available to incubated companies.
    - Under the previous model, ESA BIC offered a fixed ~€60k grant over 18–24 months.
    - Under Boost, funding can scale up significantly (in some cases up to €350k equivalent, subject to co-investment and performance milestones).
    - This allows ESA BIC to support companies with more ambitious technical development or longer path-to-market timelines.
- Carl noted that Boost also integrates private sector matching. Companies must demonstrate market interest or investor commitment to unlock the higher funding tiers, aligning public investment with market pull.

c. ESA BIC–BSGN Pipeline Synergies

- Francesco emphasised that the ESA BIC → BSGN pipeline is now a deliberately connected pathway.
    - The intent is to avoid situations where promising BIC graduates lose momentum due to a gap before in-orbit demonstration funding is available.
    - By design, BIC companies can now enter BSGN directly if they meet technical maturity and business readiness criteria.
- Mike pointed out that this continuity is one of Europe's strongest differentiators compared to other space agencies.
    - NASA, JAXA, and CSA have strong support for science and technology, but their commercial transition pathways are less integrated.
    - Europe's "stacked" approach reduces the number of handovers and keeps promising ventures within an institutional support framework.

- Francesco argued that Europe's integrated approach—BIC for early-stage + BSGN for late-stage + ESA investor network—gives it a strategic advantage in accelerating commercial uptake.
  - The model allows ESA to support companies across multiple TRL stages without losing alignment with private investors and platform operators.
- Carl added that the ESA BIC network's localised delivery (e.g., Harwell in the UK, Noordwijk in the Netherlands, etc.) ensures alignment with national industrial strategies.
  - This helps avoid a "one size fits all" problem and enables national specialisation (UK with ISAM, Germany with advanced manufacturing, etc.).
- Additional transcript note: Francesco Liucci referenced the "three axes of expansion" for BSGN:
  - Sectoral expansion — broadening beyond life sciences into advanced materials, photonics, semiconductor processing, and quantum-related manufacturing.
  - Geographic expansion — increasing pan-European engagement, with more SMEs from non-traditional space nations entering the pipeline.
  - Investment depth — increasing co-funding levels and investor participation to support more ambitious projects.

d. Filtering for Quality and Market Fit

- Francesco acknowledged that accelerators must filter serious ventures from "buzzword-driven" applicants.
  - BSGN focuses on companies with a credible market use case, not just a novel technology.
  - Investor forums and co-funding requirements help act as a natural filter—ventures must have market validation to access resources.
- Carl agreed, noting that the ESA BIC application process already filters technical feasibility and team capability before public resources are committed.

3.4 Key Takeaways

a. Current State of Play

- ESA BIC and BSGN form a linked pipeline from early-stage incubation to in-orbit demonstration.

- Boost funding increases the ability of BIC to support more technically complex or longer-horizon ventures.
- Europe's integrated model is a competitive differentiator relative to NASA/JAXA/CSA, which have strong science but less integrated commercial pathways.
- The ESA investor forum and co-funding requirements ensure market pull is embedded early in venture development.

b. Future Outlook & Direction

- Expect sectoral expansion of BSGN beyond life sciences to advanced materials, photonics, and quantum-related manufacturing.
- Geographic expansion will bring more SMEs from across ESA member states into the pipeline.
- Increased investment depth will allow larger-scale demonstration missions and more complex payloads.
- Continued pipeline integration will reduce transition gaps between early R&D and in-orbit commercial activity.
- The combination of institutional continuity + market alignment positions Europe to be a global leader in microgravity commercialisation in the post-ISS era.

Session Four: Commercial Services Platforms – Today and Post-ISS

How evolving platform capabilities, access models, and service offerings are shaping the microgravity ecosystem in the ISS and post-ISS eras.

4.1 Speakers

- Atmos Space Cargo – Phoenix free flyer re entry vehicles for cargo return.
- Alatyr – Robotic manufacturing stations for continuous processing in orbit.
- Space Cargo Unlimited (SCU) – BentoBox multi payload aggregation service.
- The Exploration Company – Nyx reusable capsules.
- Space Forge – ForgeStar high temperature return platforms for semiconductors and specialty materials.

4.2 Brief Context

This session reviewed commercial platforms providing access to microgravity and return capabilities in the post ISS era. Moderated by ESA BSGN, the discussion covered the technical offerings, operational timelines, and integration pathways into the ESA BSGN Advanced Materials Accelerator.

Five companies presented return vehicles, robotic stations, multi-payload integration systems, reusable cargo capsules, and dedicated semiconductor return platforms. The emphasis was on how advanced materials customers can align with existing services and schedules.

4.3 Key service providers

a. *Atmos Space Cargo – Phoenix Free Flyer Return Vehicles*

- It was stated that Phoenix is a cargo only re-entry vehicle designed for regular return of microgravity payloads.
- Timeline: Phoenix 1 launched in April 2025; Phoenix 2 is planned for late summer 2026; Phoenix 3 is expected early 2027.
- Capacity: Phoenix 1/2 can return ~100 kg (three mid-deck lockers). Phoenix 3 will scale up to ~1 ton return capacity.
- Heat Shield: The company described using an inflatable heat shield—lighter and more scalable than ablative or ceramic systems, “physically scalable to around 25 tonnes.”
- Flight Cadence: Post-2027, Atmos aims to operate two flights annually, with priority slots for customers seeking repeat missions.
- Pricing: The pricing approach was described as “competitive with other re-entry providers in the small to medium payload class,” particularly for aggregated middeck lockers.

b. Alatyr – Robotic Manufacturing Stations

- It was stated that Alatyr is developing compact, pressurised orbital stations for continuous in orbit manufacturing.
- Design Features: The platform will have high power and thermal budgets, compatible with a range of manufacturing processes. Equipment bays are modular, allowing “replacement or scaling without decommissioning the station.”
- Operational Model: The infrastructure remains permanently in orbit, with consumables resupplied—allowing continuous production.

- Use Cases: Continuous cycles were noted as critical for "processes that cannot be interrupted, such as extended crystal growth or thermal cycling of advanced composites."
- Timeline: Targeted commercial operations are around 2029, coinciding with post ISS transition.

c. Space Cargo Unlimited – BentoBox Multi-Payload Service

- The company presented its **BentoBox system** as a way to standardise **mechanical, power, thermal, and vibration interfaces** so multiple payloads can share one capsule.
- The purpose was described as "reducing integration delays and non-recurring engineering costs by giving customers a ready slot—power, monitoring, and structure all pre-configured."
- **Target Customers**: SMEs, early-stage companies, and academic teams who cannot fill an entire capsule.
- **Partnership**: SCU will manage **payload aggregation for Atmos Phoenix** missions.
- **Next Flight**: First SCU managed Phoenix flight is scheduled for **mid2026**; it was stated that the "manifest is nearly full."

---

d. The Exploration Company – Nyx Reusable Capsules

- Nyx was described as a **reusable cargo vehicle** with a capacity of **4 tons to LEO** and **3 tons return**.
- **Pricing**: The quoted rate is **€25,000/kg including launch**.
- **Customer Approach**: The company has built a customer database from **ISS experiment records over the last two decades**, categorising outreach into:
  - *Space Demo* (hardware demonstrations).
  - *Space Lab* (universities, pharma, biotech, cosmetics).
  - *Space Emotions* (non-technical payloads, public engagement).
- *Space Emotions* was described as a way to "create public engagement and diversify revenue."

- **Readiness**:
  - Contracts signed worth **€800M** (25% institutional, 75% commercial).
  - Next ISS mission scheduled for **August 2028** (sold out).
  - Next available commercial slots are expected from **~2033**.

c. *Space Forge – ForgeStar Return Platform*

- ForgeStar was described as a **high power, high temperature payload return platform** intended for **semiconductors, superconductors, and high-performance materials**.
- The company's role was stated as both **platform operator** and **in space manufacturer** of its own semiconductor products.
- Customer expectations were summarised as: "Semiconductor buyers are concerned with spec compliance, reliability, and yield repeatability, not the branding of 'made in space'."
- **Reusability**: ForgeStar is designed for **multiple flight cycles**, lowering return costs.
- **Next Slot**: Payload hosting opportunities are expected to open in **~2 years**, subject to vehicle readiness.

d. *Advanced Materials-Specific Offerings & Integration Pathways*

Atmos Space Cargo – Phoenix for Advanced Materials Return

- It was stated that Phoenix capsules are designed to handle temperature sensitive advanced materials including semiconductor wafers, optical fibres, and crystalline materials.
- Integration with ESA BSGN: Phoenix is listed within the ESA BSGN Advanced Materials Accelerator as an available return platform.
- Flight Availability: Phoenix 2 (mid2026) was described as "almost full," with limited space remaining. Phoenix 3 (early 2027) will add higher capacity return (~1 ton) to support TRL progression from experiment to early pilot production.

Alatyr – Continuous Processing Stations

- The company described its robotic stations as ideal for processes requiring uninterrupted production, such as extended crystal growth or thermal cycling for advanced composites.

- ESA BSGN Fit: The planned 2029 commercial start was noted to align with the post ISS advanced manufacturing roadmap, where permanent in orbit infrastructure will support production beyond short demonstration flights.
- Value for Advanced Materials: The continuous operation model was positioned as a way to maintain process stability and quality across multiple production batches before return to Earth.

Space Cargo Unlimited – BentoBox Aggregated Payload Service

- Relevance to Advanced Materials: The BentoBox standardised mechanical, power, thermal, and vibration interfaces were described as enabling multiple sensitive materials payloads to fly together, each with controlled conditions.
- Integration with ESA BSGN: SCU is a recognised integration partner for BSGN payloads, managing compliance, interface, and documentation for customers unfamiliar with microgravity operations.
- Flight Timeline: First Phoenix BentoBox flight mid-2026 (manifest nearly full). Two to three aggregated flights are targeted each year from 2027.

The Exploration Company – Nyx Large-Capacity Capsules

- Nyx was presented as capable of supporting industrial scale materials payloads due to its 3-ton return capacity.
- Customer Alignment: The segmentation into Space Demo, Space Lab, and Space Emotions was designed to match advanced materials companies at different technology readiness and market maturity stages.
- Timeline Constraints: The next ISS linked Nyx mission is fully booked for August 2028. Commercial availability is expected from ~2033, making Nyx a long horizon option for post ISS industrial planning.

Space Forge – ForgeStar for High-Value Materials

- ForgeStar was positioned as optimised for high power, high temperature payloads, with a strong focus on semiconductors, superconductors, and specialty alloys.
- Customer Focus: The company stated semiconductor customers prioritise technical compliance, yield consistency, and repeatability above all.
- ESA BSGN Integration: Forge is aligned with the BSGN Advanced Materials Accelerator, though near-term payload capacity is constrained due to its own production priorities.
- Availability: Next payload hosting opportunity is anticipated in ~2 years.

e. Market Position in Post ISS Ecosystem

- Atmos & SCU: Short cycle providers offering regular flights from 2026 for SMEs and startups needing iterative testing and TRL progression.
- Alatyr: Positioned as continuous manufacturing infrastructure from 2029, matching industry needs for process stability before scaling to commercial volumes.
- The Exploration Company: Large capacity capsule for post ISS heavy payloads, but availability aligns with long-term production plans.
- Space Forge: Specialist provider targeting niche, high value materials (e.g., semiconductors, superconductors) where microgravity offers clear commercial performance benefits.

4.4 Key Takeaways

a. Current State of Play

Current State of Play

- Multiple platforms are active or entering service to meet diverse advanced materials payload needs.
- ESA BSGN's integrated accelerator is already working with several providers to align payload selection, integration, and return schedules.
- Availability constraints exist (Nyx slots into 2033, ForgeStar ~2 years out).

b. Future Outlook & Direction

Current State of Play

- Multiple platforms are active or entering service to meet diverse advanced materials payload needs.
- ESA BSGN's integrated accelerator is already working with several providers to align payload selection, integration, and return schedules.
- Availability constraints exist (Nyx slots into 2033, ForgeStar ~2 years out).

Future Outlook & Direction

- **Short cycle flights** (Phoenix, BentoBox) will accelerate SME and academic engagement from 2026 onward.
- **Continuous infrastructure** (Alatyr) will support industrial scale production post2029.

- **Heavy lift capsules** (Nyx) will play a role in the 2030s for mass returns tied to commercial stations.
- **Specialised providers** (Space Forge) will supply narrow but high margin markets in semiconductors and quantum materials, leveraging ESA BSGN links to coordinate capacity.

Session Five: The Payload Development Journey

Unpacking the end-to-end process of designing, integrating, and flying R&D payloads — with a focus on challenges, lessons, and support provided by Commercial Service providers

5.1 Speakers

- Hubert Moser – *Flawless Photonics*
- Olga Moraru – *Voyager Space*
- Amir Ghaffari – *Photocentric*
- Daniel Campbell – *Space Pharma*

5.2 Brief Context

This session examined the payload development journey for both space and non-space companies, focusing on the technical, engineering, and operational pathways from concept to flight readiness. Moderated by Alex Goodhand, Lead Manufacturing Engineer at Satellite Applications Catapult, the panel featured experienced payload providers who outlined the practical realities of delivering hardware for microgravity missions.

The discussion highlighted how payload development is rarely linear, requiring cycles of design iteration, integration, testing, and adaptation to platform requirements. Speakers addressed common risks, such as underestimating documentation and certification timelines, and stressed that platform maturity, early ICD engagement, and engineering discipline are critical to success.

5.3 Key Points Discussed

a. *Engineering and Design Iteration*

- Hubert Moser (Flawless Photonics) described payload development as an iterative engineering cycle that always exposes new issues:

"The first CAD model rarely survives contact with the real interface."

- Typical redesign drivers include:

    - Electrical constraints (power limits, current spikes).
    - Thermal control challenges (ensuring heat dissipation without impacting adjacent payloads).
    - Mass and volume allocation limits, particularly in multi-payload missions.
- Late-stage changes are common—Hubert Moser cited projects where component enclosures required redesign after EMC failures during final qualification, delaying delivery by weeks.
- He noted that tolerances that are trivial on Earth can create fit problems during integration, particularly with tight launch clearances and multi-payload carrier constraints.
- Hubert Moser reinforced that space qualification must be integrated into initial design work, not retrofitted: payloads that delay this often face cost and time overruns.

b. Integration and Certification Challenges

- Olga Moraru (Voyager Space) explained that integration into ISS or commercial platforms is complex, with documentation requirements often underestimated by new entrants.
- NASA and ESA safety compliance requires:
    - Materials compatibility testing for flammability, off-gassing, and contamination control.
    - Hazard analysis for sharp edges, venting, stored energy, and mechanical safety.
    - Functional redundancy checks for safety critical systems.
- Qualification testing includes:
    - Thermal vacuum testing to verify environmental survivability.
    - Vibration testing to simulate launch loads.
    - EMC testing to ensure no interference with platform systems.
- Olga Moraru gave an example of a payload that failed thermal cycling due to heater control overshoot, forcing full redesign of thermal loops and retesting.
- She also raised the challenge of documentation format inconsistencies: ESA, NASA, and commercial platforms often request different safety and interface

documentation formats, adding duplicate effort for payloads intended to fly on multiple platforms.

c. *Operational Lessons from Platform Interfaces*

- Daniel Campbell (Space Pharma) explained that platform maturity has a direct impact on integration timelines:
    - Mature platforms such as Bishop Airlock (Voyager Space) and ForgeStar (Space Forge) have established interface documentation, enabling faster ICD freeze and fewer late changes.
    - Newer or custom platforms often require custom hardware mounts, non-standard harnesses, or new thermal management solutions, which extend development time.
- Daniel Campbell emphasised that locking the ICD early prevents cascading design changes:

"If your ICD is shifting late in the build, everything else starts moving too—cables, heater locations, structural balance."

- He also noted mass distribution adjustments are a recurring integration issue; payloads sometimes require last-minute ballast adjustments to meet launch provider constraints.

d. Photocentric – Additive Manufacturing Perspective

- Amir Ghaffari (Photocentric) described specific integration challenges for additive manufacturing payloads:
    - Thermal stability is a high priority issue—printers must hold narrow temperature ranges without overheating nearby payloads.
    - Power draw spikes during certain printing phases must be carefully modelled to avoid exceeding platform power budgets.
    - Data interface expectations need early clarification: unclear telemetry or control protocols can lead to last-minute software or firmware updates.
- Amir Ghaffari also noted that material approvals are sometimes a constraint: feedstock material safety must be confirmed early, as platforms may restrict certain materials due to flammability or contamination risk.
- He stressed that proactive engagement with the platform team on data rates, command protocols, and thermal sequencing at the concept stage can save months of rework.

f. *Cross Company Lessons*

- All panellists agreed that early engagement with the platform provider—particularly on power budgets, thermal envelopes, and ICD finalisation—reduces integration risk.
- Olga Moraru highlighted ongoing work to standardise harnesses, modular payload mounts, and connector systems, which could shorten integration timelines.
- Hubert Moser warned that novel materials or processes (precision optics, biocomposite systems) still introduce unique integration risks, even with standardised payload frames.
- Daniel Campbell reinforced that dynamic load compliance and mass balancing are often underestimated in early designs, creating late mechanical adjustments before flight.

5.4 Key Takeaways

a. *Current State of Play*

- Payload development remains complex, resource-intensive, and iterative, particularly for first-time payload developers and non-space companies. Even experienced teams stressed that no payload moves from concept to flight without multiple redesign loops.
- Platform interface maturity strongly influences integration success. Platforms such as the Bishop Airlock (Voyager Space) and ForgeStar (Space Forge) offer clear ICD documentation, standardised harnesses, and predictable integration steps, which minimise rework. Less mature or custom platforms require bespoke mounts, power harness modifications, and thermal redesign, adding significant engineering overhead.
- Certification compliance is still a major bottleneck. For ISS-linked payloads, NASA and ESA reviews are documentation-heavy and test-intensive, requiring:
    - Materials compatibility assessments for outgassing, flammability, and contamination.
    - Hazard reports addressing sharp edges, stored energy, venting, and redundancy.
    - Qualification tests (thermal vacuum, vibration, EMC) that can expose late-stage integration issues.
- Mass property adjustments are a frequent integration hurdle. As Daniel Campbell (Space Pharma) noted, payloads sometimes require final rebalancing

or mass redistribution in the last integration phase to meet launch provider specifications.

- Cross-platform documentation inconsistencies create friction. Olga Moraru (Voyager Space) pointed out that ESA, NASA, and commercial station providers often require different safety documentation formats—duplicating effort for payload developers targeting multiple platforms.
- EMC compliance remains a recurring risk. Hubert Moser (Flawless Photonics) highlighted that even hardware with previous flight heritage can fail EMC tests when new subsystems or payload configurations are introduced.

b. Future Outlook & Direction

- Standardisation will be the largest accelerator of payload readiness. Expansion of modular payload brackets, harmonised connector types, and common harness standards will cut down on platform-specific redesign work.
- Early ICD finalisation will remain critical. All panelists reinforced that freezing ICDs early prevents cascading late-stage changes to heaters, thermal insulation, or harnesses.
- Platform diversification will increase throughput. Providers like Voyager Space and Space Forge are building capacity for multi-payload concurrent integration, reducing bottlenecks caused by single-payload timelines.
- Incremental or modular certification models may emerge. Amir Ghaffari (Photocentric) and Campbell both suggested that pre-qualified subsystems (avionics enclosures, thermal modules) could be reused across multiple payloads, avoiding full requalification each time.
- Pre-classified payload categories are being explored by some platforms. These categories (e.g., standard microgravity experiment frames, pre-approved printer modules) could move through safety reviews faster, cutting integration timelines for repeat missions.
- Environmental envelope definition will be a growing requirement. Payloads in bioprinting, advanced optics, or high-precision materials will increasingly require tight environmental controls (humidity, temperature, vibration), necessitating early collaboration with platform integrators.
- Commercial return pathways are maturing. As Moser and Ghaffari pointed out, payload designs proven on one mission are being adapted into repeat-flight products or licensable IP. This creates a hardware product model for payload developers, rather than one-off mission builds.

- Over the next 2–3 years, improvements in interface standardisation, earlier ICD freezing, and increased platform capacity are expected to shorten payload timelines and reduce entry barriers for non-space companies entering microgravity R&D.