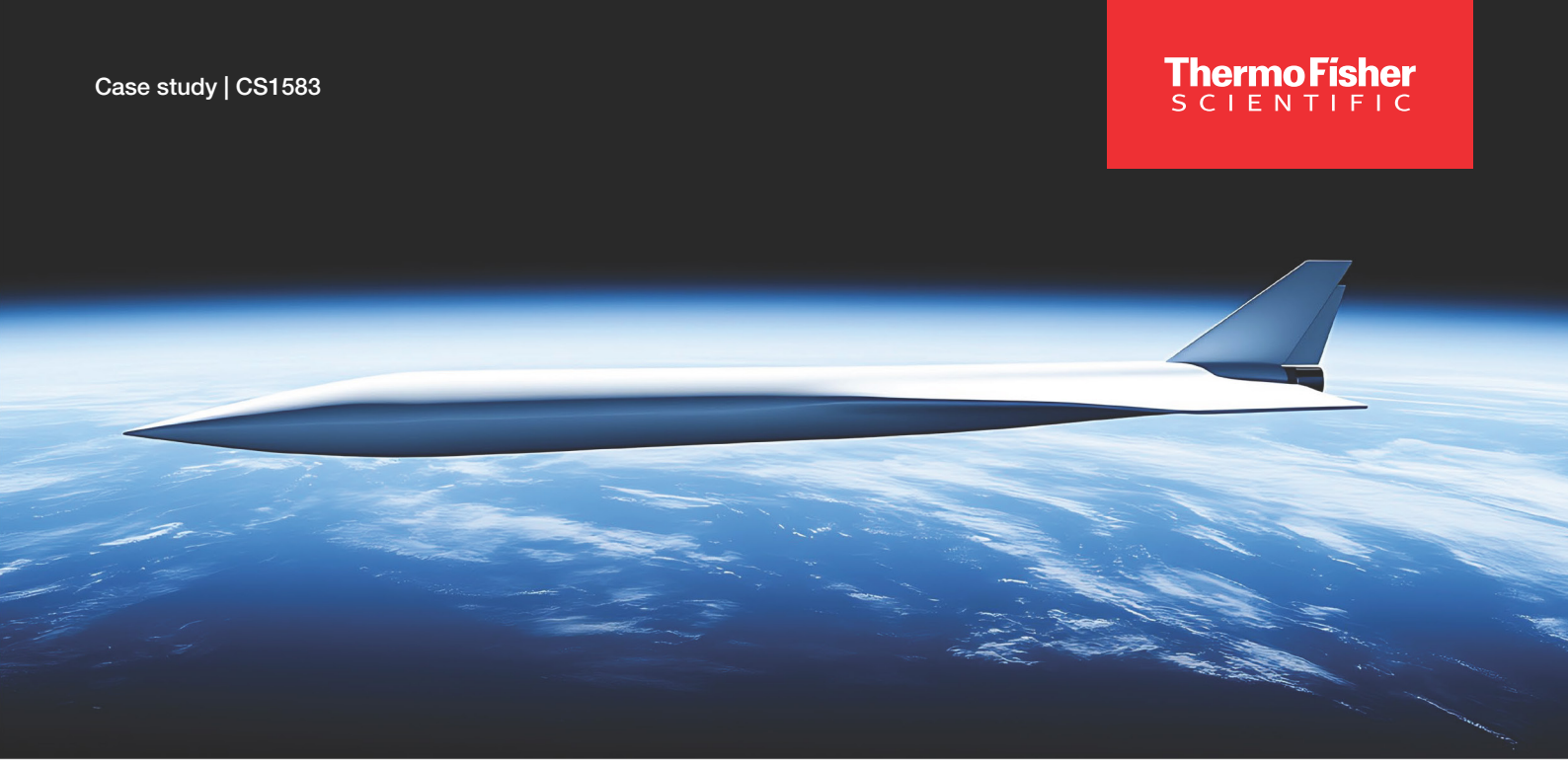

How LIFT acquired MASSBOX LALI-TOF-MS to provide state-of-the-art chemical analysis to the defense industry

Chemistry at point of need

LIFT's role in advancing the defense industry's technical capabilities

LIFT, operated by the American Lightweight Materials Manufacturing Innovation Institute, is the Detroit-based, public-private partnership between the Department of Defense, industry, and academia, committed to the development and deployment of advanced manufacturing technologies, and implementing talent development initiatives to better prepare the workforce today and in the future.

LIFT and its ecosystem accelerate technology forward into the hands of industry and the warfighter. From saving service members' lives to saving the industry and the Department of Defense time and money, LIFT continues to drive American advanced manufacturing into the future. Recent projects have had a real-world impact, such as reducing fatal rollovers in Humvees by up to 74 percent.

LIFT operates a 100,000-square-foot high bay facility, which includes an industrial metrology (MET) lab, for testing and implementing more than $50 million in state-of-the-art advanced manufacturing technologies that its 340+ members can access. Most members do not have access to such technology, but LIFT gives them the ability to perform pilot projects before investing in their own systems.

LIFT's search for chemical analysis technology

To strengthen LIFT's work in designing, building and testing new materials for future components for the Department of Defense and other industries, LIFT needed to select technology to test materials' chemical compositions, properties and performance. Their worldclass MET lab was already equipped with scanning electron microscopy (SEM), energy-dispersive x-ray spectroscopy (EDS), and other technologies used in metallographic and microstructural analysis. But LIFT had one big question left to answer: "What do we do about chemical analysis?"

Existing technology for chemical analysis, such as Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) or ICP-MS (Mass Spectrometry), were options that LIFT considered. However, there are significant drawbacks for solid materials, such as the cumbersome equipment, complicated operational procedures, limited scope of elemental results, and significant operational expenses including gases and consumables. LIFT was aware of the need for innovation in this space and began to seek alternative solutions.

LIFT + MASSBOX LALI-TOF-MS

LIFT's CEO Nigel Francis met Ellen Williams, EXUM's EVP of Business Development, at the Defense Manufacturing Conference (DMC), where they first learned of the EXUM™ MASSBOX™ LALI-TOF-MS. Nigel promptly connected Ellen with LIFT's Director of Engineering, John Keogh, who was actively procuring the equipment needed for their world-class facility. This chance meeting helped LIFT answer their question about innovation in chemical analysis and led to the purchase of a MASSBOX LALI-TOF-MS for their MET lab and a sound partnership.

The MASSBOX LALI-TOF-MS rapidly determines the chemical composition of any solid material, from a pressed powder to a solid part. It is the industry's first Laser Ablation Laser Ionization Time of Flight Mass Spectrometer (LALI-TOF-MS) capable of trace level detection for virtually the entire periodic table. Addressing the current state of challenges in solid state analysis, MASSBOX LALI-TOF-MS provides quantitative chemical analysis of metallic, trace, and low-mass (e.g., carbon, oxygen) elements in a single analytical session, ultimately reducing the need for additional lab tests, specialized staff, and the time it takes to analyze test results. Figure 1 illustrates how MASSBOX LALI-TOF-MS works.

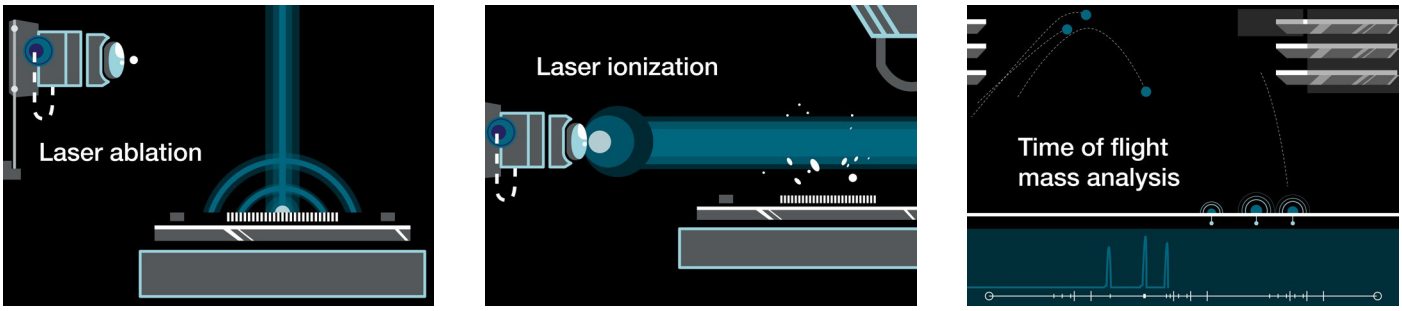

Figure 1: A) Ablation laser fires perpendicular to the sample's surface. The laser spot size is adjustable from 5-150 microns; B) Secondary laser performs multiphoton ionization of neutral particles created by ablation process; C) Ions are separated by time-of flight mass spectrometry and detected with a multichannel plate (MCP)

LIFT members, made up of original equipment manufacturers, material suppliers and software providers across government, industry and academic spaces, have access to the MASSBOX LALI-TOF-MS in its Detroit technology accelerator and pilot facility. "As LIFT continues its focus on the intersection of materials, processing and systems engineering, this new tool is a game changer for LIFT and our broader ecosystem," said Noel Mack, Chief Technology Officer, LIFT. "It is sure to serve as a vitally important resource in advancing high-tech research and development in Detroit and beyond."

Chemical data at the point of need

Traditional high-performance techniques like ICP-OES and ICPMS involve acid digestion for the most accurate chemical analyses. Such precise sample preparation procedures require expertise to properly execute, correct for signal interferences, and perform calibrations. These processes also demand a clean lab and significant expenses for acids and other consumables. Addressing the challenges of conventional instruments, the MASSBOX LALI-TOF-MS provides trace-level detection of the full periodic table in a compact, desktop package. It uses a standard power cable, and its intuitive operations don't require chemistry expertise. Figure 2 shows MASSBOX LALI-TOF-MS's position in LIFT's MET Lab.

Figure 2: LIFT's Senior Metallurgist, Daniel Baker, explains how the MASSBOX LALI-TOF-MS operates as it analyzes a set of aluminum powder samples.

Because MASSBOX LALI-TOF-MS directly analyzes solid materials, it does not require acid digestion, a clean lab, or trained chemists. Its simplified operations empower users of LIFT's facility to quickly verify material quality or investigate failures.

Nickel weld analysis

The analytical process involved rastering a small area of 5.475 mm by 4.875 mm with a 75-micron laser spot size. The user can adjust the laser spot size depending on the desired resolution. For this study, the analyzed area encompassed both the nickel weld and the steel substrate, as shown in Figure 3.

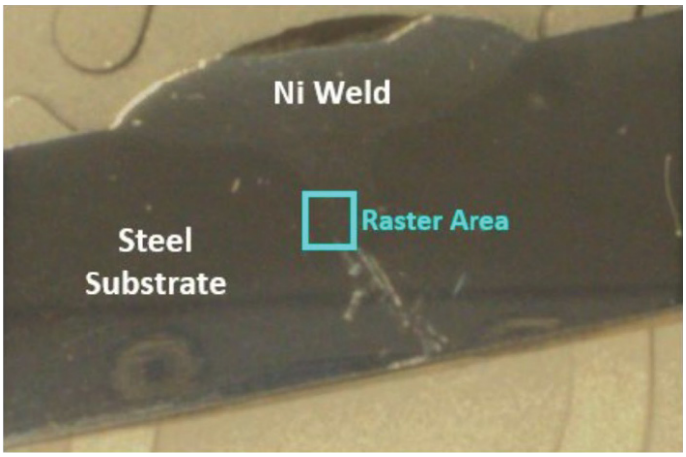

Figure 3: Image of the welded sample taken by MASSBOX's macrocamera. The blue rectangle shows the raster area of analysis.

LIFT rastered the area twice so the first pass captured chemical data from the sample's surface, and the repeat pass revealed chemical variations below the ablated surface. This process of repeated elemental maps allows the user to create depth profiles and ultimately 3D reconstructions of materials.

Results

MASSBOX LALI-TOF-MS generated chemical maps displaying spatial distributions for individual elements of interest. Figure 4 shows maps for nickel (Ni), iron (Fe), chromium (Cr), titanium (Ti), and aluminum (Al), and results are not limited to the elements displayed here. Each pixel is a 75-micron laser spot and includes a full mass spectrum of data. The color scale indicates relative concentrations, with lighter blues denoting higher concentrations. Notably, the high (light blue) concentration of Ni in the top right corner is the welded area. As expected, Ni concentration is high on the weld and low (dark blue) on the steel substrate. The weld boundary appears as a narrow gradient only a few pixels (~200 micron) across.

The top row presents results from the sample's surface, while the bottom row displays the elemental map acquired below the sample's surface. The Fe map exhibited a more obvious contrast below the surface, despite Fe being the major element in steel. This lack of contrast indicated dilution of the base steel into the Ni weld area in the map's top right corner. Concentrations appeared relatively similar across the weld and substrate on the surface map.

Distributions of Cr and trace elements, Ti and Al, also exhibited changes from the surface to the repeat pass. Repeat maps allow users to create depth profiles of any element of interest. The amount of material removed in each layer is dependent on the user-defined laser power and material type. For most metals, the ablation laser removes 100s of nm per layer, allowing high-resolution depth analyses.

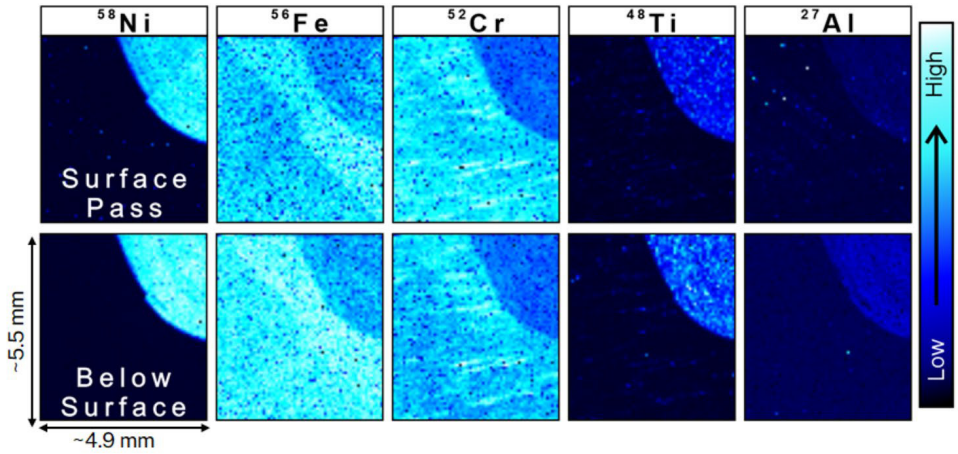

Figure 4: Mapping results acquired by the MASSBOX LALI-TOF-MS on a welded sample. The analysis area is 4.9 mm by 5.5 mm with a 75-micron laser spot size. The color scale shows relative concentration of each element with lighter colors indicating higher concentrations. The top row shows results from the first pass on the sample's surface and the bottom row is from the repeat pass, below the ablated surface.

Conclusion:
A game-changer for advanced manufacturing

The detailed nickel weld analysis underscores the MASSBOX LALI-TOF-MS's capacity for mapping and depth profiling. The study allowed LIFT to characterize the nickel weld gradient and dilution of substrate material into the weld. By comparing results from the surface to the second layer, surface contaminants were excluded, and it revealed elemental variations in depth. The MASSBOX LALI-TOF-MS's depth profiling capabilities are also useful for analyzing coatings, surface finishes, and oxide layers. In addition to the transition metals shown in Figure 4, results also included light elements like carbon and heavier elements, molybdenum and niobium. Traditional instruments fall short in quantitatively measuring both light and heavy elements in the same analytical session.

This analysis exemplifies the MASSBOX LALI-TOF-MS's impact on advancing materials research and development, further solidifying its role as a game-changer in the realm of advanced manufacturing. Instead of investing in a full clean laboratory and the operational expenses of traditional techniques, LIFT procured an innovative chemical analysis tool. Now, LIFT acquires impactful chemistry data in their MET Lab, at the point of need.

Elemental mapping

Depth profiling

Rapid screening

Quantitative analysis

Thermo Fisher Scientific is an authorized distributor of the EXUM MASSBOX LALI-TOF mass spectrometer in Europe, United Kingdom, and China. For all other regions, please contact us at marketing.ppa@thermofisher.com.

Learn more at **thermofisher.com/massbox**