

A Case Study Analysis with the JUICE/JoEE Instrument

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ESA's JUICE Mission and JoEE Instrument

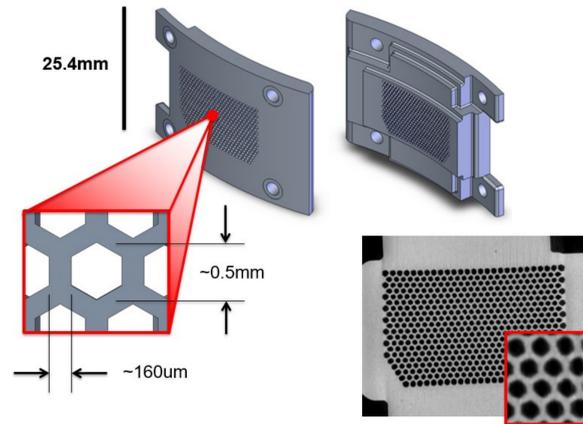
- Jupiter Icy moons Explorer (JUICE)
 - To explore Jovian system and Ganymede, Callisto, Europa for habitable environments



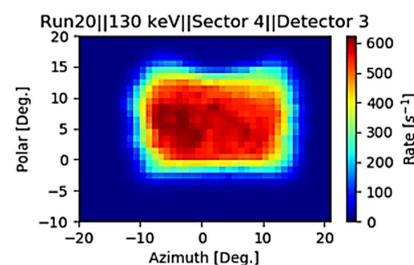
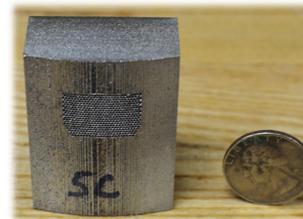
- Jovian Energetic Electrons (JoEE)
 - Magnetic spectrometer with solid state detector stack provides clean electron measurements between ~20keV—1.5 MeV
 - To probe acceleration mechanisms, magnetic field topology, and boundaries

- Circular design with nine individual sectors that create a ~100-600 Gauss magnetic field
- Requires highly directional hole geometry for collimation - to confine particle trajectories with adequate foreground signal while shielding fragile detectors

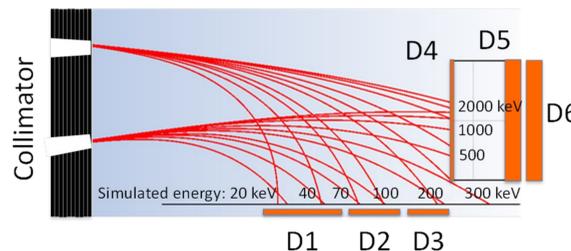
Collimator Design



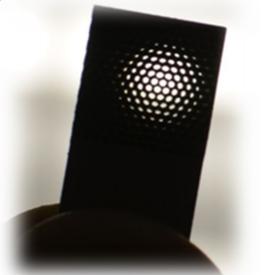
- 9 collimators assembled via interlocking features
- Material: 316L Stainless Steel
- Hexagonal holes for greater packing density with each hole focused along unique vector
- Each segment built individually for better hole resolution
- JHU/APL developed new machine parameters for laser pathing and control for thin-walls application
 - ~160 μm walls achieved (vs. 400μm typ. commercial)
- Post-processing
 - Extensive machining to achieve tighter tolerances
 - Ultrasonic cleaning
 - CMM inspection of exterior features



- Demonstrated angular properties met requirements



Additive Manufacturing (AM) Approach



- Collimator Requirements
 - Nonmagnetic, dense material
 - 22.5° azimuth / 12° polar FOV
 - 518 tightly packed holes, ~Ø0.5mm
 - Instrument size / mass limits

- Benefits of AM
 - Build parts unobtainable with conventional manufacturing
 - Smaller, more compact structures
 - Complex internal features / lattices

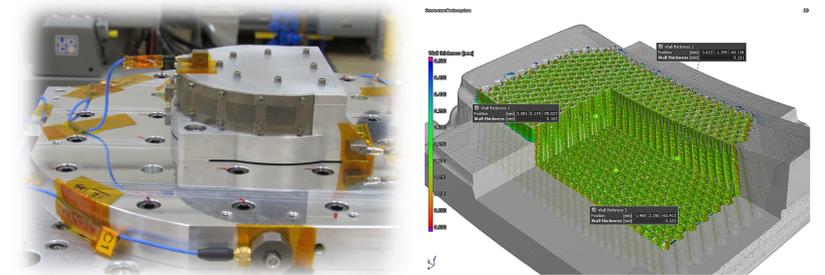


- Metal Powder Bed Fusion (PBF) process selectively fuses layers of powder metal with laser

AM fabrication, inspection, materials characterization, and testing all performed at JHU/APL

Spaceflight Qualification

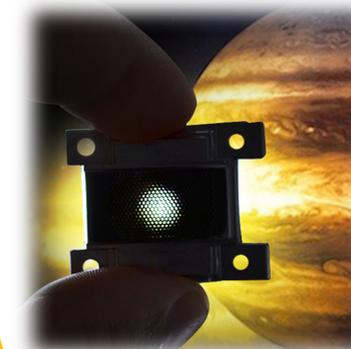
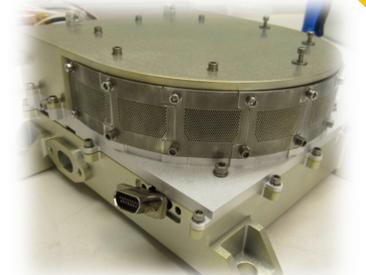
- JHU/APL collaborated with NASA Marshall to utilize new MSFC-STD-3716 and -3717 standards
 - Clear documentation of risk, metallurgical process, material testing, and part production



- Proof testing (vibe, shock, thermal) combined with X-Ray Computed Tomography (XRCT) inspection
- JHU/APL developed novel methods using commercial XRCT software for complex volumetric analysis
 - Wall thickness, focus location, porosity, defects

Future Prospects

- Complex geometry enabled by AM allowed for more efficient instrument collimation
- AM requires new inspection and characterization methods beyond proof testing



- JHU/APL is leading AM R&D efforts and investigating spaceflight applications:
 - Copper materials for thermal management
 - Tungsten materials for shielding and collimation
 - Topology optimized structures for mass / stiffness