The Road to First Light: Collaboration Between Science and Industry on James Webb's NIRCam

On Dec. 25, 2021, NASA successfully launched the James Webb Space Telescope (JWST) on a mission to reveal what our universe looked like 13.5 billion years ago, when the first stars and galaxies took shape after the Big Bang. Tasked with capturing those "first light" images is the telescope's Near Infrared Camera (NIRCam), one of the most sensitive infrared cameras ever built.

NIRCam is the product of more than 20 years of collaboration between a team of scientists at the University of Arizona and a team of engineers at Lockheed Martin. Over the course of two decades, it's not surprising that building an instrument for the largest, most powerful space telescope ever made required steadfast partnership and stepping outside of the realm of what science and engineering think is possible.

The collaboration between the University and Lockheed Martin on what became Webb began in 1998 with a project that wasn't NIRCam.

"An ad hoc science group formed out of a call by NASA for ideas on how the instrument suite on the JWST might be handled," said Dr. Marcia Rieke, Regents' professor of astronomy at the University of Arizona and the NIRCam Principal Investigator. "We ended up teaming with Lockheed Martin on this instrument suite concept, which we now call the Integrated Science Instrument Module, that proposed an economical way to build all the instruments."

However, Webb was an international project with partners in the U.S., Canada and Europe, and eventually, the idea of one entity building all the instruments was scrapped in favor of each country being given the opportunity to submit proposals for instruments.

The University of Arizona and Lockheed Martin team proposed an innovative refractive instrument design that was more compact and light weight than conventional reflective designs and which helped the team win the contract to build NIRCam.

Translating Science into Engineering

NIRCam started with science, specifically: science goals.

The University of Arizona translated these science goals – some of which were determined by the University and some of which were determined by the scientific community's priorities – into broad engineering requirements. From there, Lockheed Martin engineers flowed broad requirements down into more specific requirements that touched everything from the electronics to the optics.

As the Lockheed Martin team began designing NIRCam to meet these requirements, collaboration with the University was critical.

"It was important to be close to the science because we weren't building this for abstract ideas, we were building this for a science team with real goals to advance human knowledge," said Dr. Alison Nordt, Lockheed Martin's Director of Space Science and Instrumentation, who led development of NIRCam. "I think that close relationship with the science team really gave everybody a sense of purpose, much more so than just building hardware to a requirement in a document."

The partnership required the scientific community and industry to learn how to understand each other and, sometimes, come to compromises, said Dr. Nordt.

Compromise took the form of scientists modifying certain requirements to fit cost limits and what was feasible from an engineering standpoint and industry understanding enough of the science goals to make key build decisions.

Take NIRCam's coronagraph, for example.

"One of the goals of NIRCam was to add a coronagraph for science work related to exoplanets," said Dr. Nordt. "If we on the engineering side had just taken the mission at face value – what does our contract say? – we would have dropped the coronagraph, but we understood what was important to the scientific community and knew we had to make that goal work."

Rewriting the Textbooks on Manufacturing

One of the biggest challenges the University and Lockheed Martin faced was building an optics system with a stable and acceptable wavefront error. Wavefront error is an anomaly that occurs when light passes through an optics system that causes the reflected or transmitted light waves to deviate from their perfect shape.

"NIRCam's wavefront error had to be exceptionally good and remain stable throughout the mission," said Dr. Nordt. "Arm-wrestling among all the different potential error sources and building an instrument with that kind of precision and stability was challenging."

That's where, in partnership with the University and subcontractor Optical Solutions Inc., Lockheed Martin put a new spin on the standard.

"Because the wavefront error was so challenging, a lot of the manufacturing processes that you would normally follow to create these optics at the time just wouldn't work," said Dr. Nordt. "So, we had to re-write the textbooks."

When trying to meet this requirement, the partners discovered that the traditional design approach for mounting lenses on the instrument produced too much variability in the wavefront error during testing.

"So we decided instead of mounting them traditionally, we had to bond some of the optics," said Dr. Nordt. "And the idea of bonding optics that would go to cryogenic temperatures was unheard of."

But a large-scale development effort by Lockheed Martin made the impossible possible, and the resulting bonding technique was successfully used on Webb, as well as several other missions.

Testing Together

Outside of build and design, testing NIRCam was another opportunity for close knit collaboration between science and industry.

"Testing on NIRCam was a lot like doing astronomy work," recalls Dr. Rieke. "The science team could help a lot in terms of not just sitting on console and running the commands but looking at the data and understanding what it meant in terms of the requirements that had been laid out."

And that strong collaboration came particularly in handy when the two teams didn't like what testing showed them.

"I remember when we first got light through on the first cryo test, there were these strange glints of light in the focal plane," said Dr. Nordt. "The science team flagged right away that this was not what we were supposed to be seeing, and it turned out we had a stray light issue that we were able to work closely to resolve."

Collaboration for Mission Success

Recently, the James Webb Space Telescope hit a significant milestone as it produced its first images of starlight captured by NIRCam – a visual testament to a strong partnership between science and industry.

Members from both the University and Lockheed Martin teams witnessed the images of first light together in person on console and via Zoom.

"We were ecstatic and just absolutely euphoric that we were getting light through," said Dr. Nordt.

Over the coming months, Webb will continue to tune and prepare its mirrors to produce clearer and sharper images.