Astronomy is one of the oldest and truest champions of optical science. Astronomy brings together a majority of major optical disciplines, including optics, detectors, interferometry, spectroscopy, and lasers, among others. When armed with electronics and information technology in addition to the power of optics, astronomy attempts to answer the most important questions of our time.

“Astronomy seeks information related to the very origins of our universe,” says Jim Bilbro, SPIE President and assistant director for technology at NASA’s Marshall Space Flight Center (Huntsville, AL), “and to me that’s a fascinating topic that appeals to the general public as well as astronomers.”

Sergio Volonte, coordinator for the astronomy and physics program at the European Space Agency (ESA; Paris, France) science program directorate, identifies a second major theme to modern astronomy in addition to universal origins: the exploration of exo-planets, or planets outside our solar system. “Why planets? Two reasons,” Volonte says. “The first reason is the discovery of another terrestrial planet, and then the possible discovery of life forms. When you have that, you can study planetary systems in various levels of evolution and that will help us better understand our own system.”

Unlike the gradual development of astronomy tools during the past 6000 years, astronomy has exploded in recent decades. “We’re at a crossroads in astronomy,” explains Jim Breckinridge, chief technologist for NASA’s Origins program. “We’re beginning to open multiple windows on the universe, simultaneously. There’s Chandra [X-Ray Telescope] at one end, the Herschel far-infrared and submillimeter telescope at the other end, and Hubble in the middle. I don’t think we’ve ever been able to go from the x-ray to through the sub-millimeter region of the spectrum before.”

Beyond expanding astronomical access to an increasing spectral range, wavefront sensing, control, and metrology systems are pushing the capabilities of telescopes—both space-borne and terrestrial—allowing astronomers to resolve smaller segments of the sky and view ever more distant objects. “Measuring the deformation of the structure and correcting through the use of control algorithms are breaking through barriers of spatial frequency,” Breckinridge adds. “We have no idea where this road will take us. We can theorize, but it’s really wide open.”

Terrestrial telescopes’ use of guide stars and adaptive optics to compensate for atmospheric interference, and space-borne observatories’ use of interferometers and adaptive optics systems to correct for spacecraft micromotions, have allowed both categories of telescope to scan the sky in fractions of arc seconds rather than the previous limit of 1 arc second. When combined with larger electromagnetic collection optics and increasingly sensitive detectors, the results are telescopes that can see farther through space and time than ever before.

Although improvements to optical systems including wavefront control systems, detectors, optics, and electronics have brought astronomy to today’s crossroads—they will not leave it there. Scientists and engineers are already tackling new technical challenges to further increase the utility of the latest generation of astronomical telescopes. “We’re developing our ability to see objects with
ultrahigh contrast,” Breckinridge explains. “We need to develop ways to image very faint sources in the presence of bright objects, such as a planet around a star. By faint, I mean a contrast of $10^9$, and if we’re going to make any kind of measurement, then we need a contrast ratio of $10^{12}$. Low noise detectors and hypercontrast optics will be the key to resolving these faint objects, Breckinridge concludes.

Looking back on the marriage of optics and astronomy, it is easy to be surprised by how far the two sciences have come together, but what is likely to be even more astounding is how these systems will change in the future. “Today, we are making decisions about space telescopes such as [James Webb Space Telescope] based on the current state of the art in mirror technology. We are choosing solutions that are simple and stable to minimize risk to the taxpayer,” explains Phil Stahl, optical component technical lead at NASA for the James Webb Space Telescope. “But, the telescopes we’re going to build 10, 15, 20 years from now need to look quite different. And we need to continue pushing mirror technology development to enable future telescopes with new and different materials, configurations, and architectures.”

Astronomers from around the world soon will get a glimpse of what the future may hold, according to ESA’s Volonte. By the end of this year, the ESA expects to complete a long-term plan that details space-borne observatory development out to 2025.

For more information on the current development of optical sciences and astronomy, visit www.spie.org/info/as to learn more about SPIE’s upcoming Astronomical Telescopes and Instrumentation conference, which is scheduled for 21–25 June 2004 in Glasgow, Scotland.