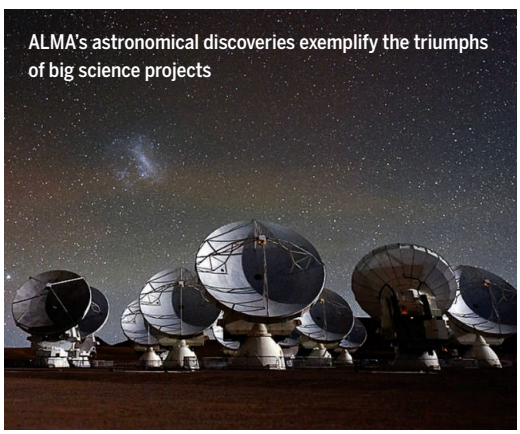
EDITORIAL

Big science is hard but worth it

Big science is hard. It is the throw-deep approach that pushes technology to the edge to achieve stunning breakthroughs that dramatically extend the frontiers of science, while inspiring the next generation of scientists and capturing the imagination of the public. The Large Hadron Collider (LHC) produced the Higgs boson, a particle that explains why all other particles have mass and whose name is now known around the world; the Atacama Large Millimeter and Submillimeter Array (ALMA) revealed some of the earliest galaxies, as well as a nearby planetary system that has a striking resemblance to our own; and for 25 years, the Hubble Space Telescope has dazzled us with its discoveries and iconic astronomical images. But before they became famous for discoveries, these and other big projects were infamous for their problems. What are the challenges for big science, and what does it take to succeed?



ALMA's astronomical discoveries exemplify the triumphs of big science projects

"It is the throw-deep approach that pushes technology to the edge..."

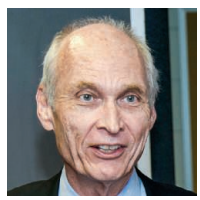
Four hundred years ago, Galileo urged "measure what is measureable" and "make measureable that which is not." Until recently, the latter almost always involved a single scientist or small group inventing new instrumentation (and often still does). But as science has matured, advances now often require big teams and expensive facilities. The technological challenges are daunting, from operating a 100-ton, 27-km superfluid helium system at 1.9 kelvin at the LHC to preparing for the unfolding of the James Webb Space Telescope's (JWST's) 18-segment, 6.5-m mirror, 1.5 million km from Earth in 2018. Sociological, budgetary, organizational, and cultural issues can be even more difficult. Big-science time scales are longer, making it harder for graduate students to complete thesis work and for postdocs and assistant professors to achieve results that advance their careers in a timely way. Projects are so large and expensive that proper management is complex, and even small budget overruns have broad programmatic impact. Big science often involves partnering, and whether it is multiple funding agencies, several countries, or a public/private partnership, getting partners with varying cultures to act coherently is difficult.

And yet big science can overcome these hurdles and be triumphant. From my experience at the U.S. National Science Foundation with big projects, including ALMA and the LHC, I see four key ingredients for success at this scale. All of the stakeholders, from the science community to the funders, must view the science as truly worthy of a big-science approach and must be committed to seeing things through during good times and bad. With one-of-a-kind, envelope-pushing projects, problems will undoubtedly arise, but with the appropriate management structure, independent oversight, and project contingency funds, they can be identified quickly and solved. Partners must be committed to the project and to their well-defined, agreed-upon responsibilities and willing to delegate authority to a managing partner or to central project management. Last, but not least, all involved must be honest and realistic about both progress and problems and willing to make hard decisions, whether it be descoping, raising additional funds, or even cancellation.

Four years ago, the U.S. Congress came close to cancelling Hubble's successor, the JWST. Although the details of how big projects suffer near-death experiences vary, JWST's problems were not atypical: The budget had gotten out of control, the management structure was insufficient, and there was an all-around failure to acknowledge difficulties. Thankfully, the science community—not just astronomers—recognized the importance of game-changing projects such as JWST and rallied to its support. NASA made major management changes, and Congress committed to the needed funding, despite tough federal budgets. Today, JWST still faces substantial technical challenges as testing and systems integration begin, but it is on schedule and on budget with appropriate resources to address contingencies.

When we see the stunning images from JWST and hear about the breakthroughs, we will all be proud of what was accomplished and know that it was worth the hard work and big investment.

– Michael S. Turner



Michael S. Turner is the Rauner Distinguished Service Professor and director of the Kavli Institute for Cosmological Physics at the University of Chicago, Chicago, IL. E-mail: mturner@kicp.uchicago.edu

PHOTOS: (TOP RIGHT) UNIVERSITY OF CHICAGO; (INSET) ESO/C. MALIN

10.1126/science.aaa3581

Big science is hard but worth it

Michael S. Turner

Science **348** (6233), 375.
DOI: 10.1126/science.aaa3581