Testimony of

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Wide Field Infra-Red Survey Telescope (WFIRST)

before the

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Chairman Wolf, Ranking Member Fattah, distinguished Members of the Committee, thank you for the opportunity to testify about the Wide Field Infra-Red Survey Telescope, WFIRST. The National Academy's *New Worlds, New Horizons* 2010 decadal survey report (NWNH) ranked WFIRST as the highest priority "large" space mission for the coming decade. The NWNH report describes WFIRST as "an observatory designed to settle essential questions in both exoplanet and dark energy research, and which will advance topics ranging from galaxy evolution to the study of objects within our own galaxy." My request is to include $8 million for WFIRST in the budget for NASA.

The 2010 decadal survey committee tailored its recommendations to the tight budgetary constraints forecast for the coming decade. It adopted a far more extensive and more conservative cost estimate methodology than previous decadal surveys. In an earlier decade, WFIRST might well have been classified as "medium-sized." It will nevertheless exploit US industrial expertise in infrared detectors to enable Nobel Prize-class science. For the past year, the WFIRST Science Definition Team has been working with NASA to improve the WFIRST design. The new designs under development are simpler and likely to be less costly than an interim design developed in 2011. I ask you for continued funding at the FY 2012 level of $5.7 million, plus an additional $2.3 million to work with industry to develop a new generation of infrared detectors that can both enhance the science output and decrease the ultimate cost of the WFIRST mission.

WFIRST is the highest priority space mission for the next decade: For the past six decades the US astronomical community has come together once every ten years under the auspices of the National Academy of Sciences to prioritize projects for the coming decade. NASA, NSF and DOE underwrite these surveys to guarantee that they have a complete and broadly based view of the opportunities for discovery. The 2010 Astronomy and Astrophysics Decadal Survey identified WFIRST, the Wide Field Infra-Red Survey Telescope, as its highest priority for a "large" space mission. This choice was driven by the realization that several distinct astronomical sub-communities sought to build essentially the same telescope, albeit for very different purposes. But almost as important was that WFIRST was one of the smaller options for a "large" mission and that its technical readiness level was among the highest. This seemed prudent given the then-expected budgetary constraints.

The wide appeal of WFIRST to the astronomical community is illustrated by five "cornerstone" projects that anchor the mission design. These five cornerstone projects carry out the three science goals laid out in the NWNH report. Three of these projects address cosmic acceleration, which is referred to by Nobel Laureate Frank Wilczek as "the most mysterious fact in all of physical science, the fact with the greatest potential to rock the foundations."

1) The history of cosmic acceleration using supernovae: The 2011 Nobel Prize was awarded to 3 Americans for the 1998 discovery that, contrary to expectation, the expansion of the universe is accelerating rather than decelerating. WFIRST will vastly improve upon their results, first by observing far greater numbers of supernovae and second by measuring their infrared brightnesses rather than their brightnesses at visible wavelengths.

2) The history of cosmic acceleration using galaxy clustering: There is a circular ripple in the observed distribution of galaxies that was frozen into the universe when it was less than one one-hundredth of a percent of its present age. One can measure the acceleration of the universe at different times in the past by measuring the size of this circular ripple. This technique is more accurate than the supernova method at times earlier than half the present age of the universe. The combination of the two methods provides a much more complete acceleration history.

3) Cosmic acceleration via weak gravitational lensing: There are two broad classes of explanations for cosmic acceleration. It might be due to a heretofore unidentified constituent of the universe (sometimes called "dark energy"), or it might be due to the breakdown of Einstein's theory of general relativity. The breakdown of Einstein's theory can be tested by measuring the distortion of the shapes of distant galaxies by intervening nearby galaxies. If general relativity *is* correct, this "weak" gravitational lensing gives the best measurements of cosmic acceleration at ages intermediate between those best measured by supernovae and those best measured by galaxy clustering.

4) Census of cool extrasolar planets: WFIRST will complete the statistical census of planetary systems in the Galaxy, from habitable Earth-mass planets to free floating planets, including analogs to all of the planets in our Solar System except Mercury. While more than two thousand extrasolar planets are known, the vast majority of these planets are much hotter than the Earth, because they orbit very close to their host stars. WFIRST will employ the gravitational lensing method, first developed by Einstein, to find planets down to the mass of Mars in orbits ranging from that of Venus to planets at

orbital distances beyond any of the Solar System's planets. In fact, WFIRST will also find rogue planets as small as Mars that have been ejected from the gravitational grip of their host stars. When combined with the hot planets found by Kepler, WFIRST will provide a complete census of extrasolar planets down to below an Earth-mass.

5) An infrared survey of our Milky Way: Perhaps 80% of the stars in our own Milky Way galaxy are hidden from view by intervening dust that absorbs their starlight. Dust absorption is much diminished at infrared wavelengths, permitting a more penetrating look into the depths of the Milky Way.

Beyond these cornerstone goals, roughly 20% of the observing time on WFIRST would be open to competition, drawing on the best ideas of US astronomers. Data acquired for the cornerstone projects would be archived and made broadly accessible. The weak lensing survey in particular promises to identify both the brightest galaxies in the early universe and the faintest stars close to the Sun.

Context: As with WFIRST, the James Webb Space Telescope (JWST) was the highest priority of a decadal survey and again like WFIRST, it exploits US leadership in infrared detector technology. But the two are otherwise as different as it is possible for two telescopes to be. Where JWST will act like a telephoto lens, enabling the deepest images of the universe, WFIRST will act like a wide-angle lens, giving a broad view. JWST's light gathering power comes from the 18 segments of its primary mirror. This dwarfs WFIRST's primary mirror, which is roughly equal in size to just one of these segments. But where the imager on JWST will have 8 million pixels, WFIRST will (coincidentally) have 18 times as many – 144 million pixels. With each pointing WFIRST will obtain images of a region 100 times as large as the JWST field of view. Ground-based astronomers have long recognized the need for such complementarity. Most of the world's major observatories have both large, deep-sky and smaller, wide-field capabilities. Only now have advances in infrared detector technology made it possible to put a wide-field infrared telescope in space.

In the time since the 2010 decadal survey the European Space Agency (ESA) has approved the Euclid wide field survey mission. Of the five cornerstone programs described above, Euclid will carry out only two. Europe does not produce comparable infrared detectors, so Euclid must work primarily at optical wavelengths. Upon the recommendation of a recent NRC panel, NASA and ESA are currently negotiating a modest US contribution of infrared array detectors to Euclid in return for access to Euclid data for US astronomers. These detectors would be used for the Euclid galaxy clustering survey but not for its weak lensing survey. The NRC panel strongly endorsed this participation but emphasized that the Euclid contribution to the decadal survey's goals for WFIRST will be limited at best. Quoting from the NRC report "NASA should make a hardware contribution of approximately $20 million to the Euclid mission to enable U.S. participation. This investment should be made in the context of a strong U.S. commitment to move forward with the full implementation of WFIRST in order to fully realize the decadal science priorities of the NWNH report."

Progress since the decadal survey: The recommendation of the 2010 decadal survey was based on a design submitted in mid-2009. In December 2010 NASA appointed a Science Definition Team (SDT) to come up with a design reference mission for WFIRST. That team produced an interim report in July 2011 and will produce a final report in June 2012. The latest design is both simpler than that originally envisaged in the decadal survey and will produce better images. Moreover, advances in infrared imaging technology in the intervening three years make it possible to consider a mission with 50% more pixels, with a commensurate gain in science output. In concert with the Science Definition Team, the project study group, drawn from the Goddard Space Flight Center (GSFC) and the Jet Propulsion Laboratory (JPL), is working to bring both the new telescope design and the new generation of detectors to full maturity, "retiring" any outstanding risks that might be associated with either.

Is WFIRST a flagship mission? Although WFIRST will provide Nobel Prize-class science, it is not a flagship mission in the sense of the Hubble Space Telescope (HST) or JWST. The WFIRST telescope mirror is relatively small, with a 1.3 meter diameter primary mirror and only a single, wide field-of-view instrument, compared to the 4 instruments each on HST and JWST. The previous mission most similar to WFIRST is Kepler, which has a 1.4 meter diameter primary mirror and a single, wide field-of-view instrument, but which observes in the optical rather than the infrared. The WFIRST project should be run more like the Kepler mission, with a small, dedicated team developing the mission from an early stage.

WFIRST funding: NASA's proposed FY 2013 budget has a line for WFIRST but no funding. This is not the "strong U.S. committtment to move forward with the full implementation of WFIRST" urged by the NRC Euclid panel. Indeed if NASA follows through on the recommendation of the NRC Euclid panel (which I supported and still support), it would put NASA in the curious position enabling and enhancing a European mission, Euclid, while putting the brakes on the highest priority recommendation of the decadal survey.

The 2010 decadal survey commissioned external Cost Assessments and Technical Evaluations (CATEs) for all of its major recommendations. The resulting figure for WFIRST was \$1.6B, including healthy margins for contingencies. The NWNH cost estimate methodology was far more conservative than that used by previous decadal surveys. The independent cost modeling, done by the Aerospace Corporation, was based on historical costs of previous missions. They estimate a 70% chance that WFIRST will cost less than estimated. The new mission designs under study by the WFIRST SDT and study team at GSFC and JPL are technically simpler, and may cost less than this once a full cost assessment is done. NASA's FY 2012 expenditures for WFIRST will be roughly

$5.7M. This funded the efforts of the Science Definition Team and of the project study teams at NASA's GSFC and JPL.

The estimated time from an official WFIRST new start to launch is 7 years, and a December 2010 NRC report recommends a launch by FY 2022, implying a new start in 2015. Fortunately, the optimal WFIRST schedule is for a low level of funding (for the large infrared focal plane) for the first few years, followed by an increase in funding as the JWST cost decreases just prior to its launch. This funding profile is therefore compatible with the future budgets anticipated for NASA.

While WFIRST could start immediately with the 2009 infrared detector technology considered by NWNH, a new generation of infrared detectors is approaching readiness that would make for a scientifically more powerful mission and perhaps a modest cost reduction. A NASA investment of $2.3 million in FY 2013 to work with industry to help advance the technical readiness level of the new generation of 16 megapixel infrared detectors would yield a handsome return in science and perhaps savings.

FY 2013 funding request: A total of $8 million is requested in FY 2013. This includes $5.7 million for continuation of current WFIRST study work and an additional $2.3 million for work on infrared detectors.

Thank you again for the opportunity to tell the committee about WFIRST. I hope that my testimony will prove helpful. I will be happy to answer any questions that you might have.