Table 1: Science Traceability Matrix.

DOE & NAS SCIENCE GOALS (P5* Strategic Plan; New Worlds New Horizons 2010)	SCIENCE OBJECTIVE	SCIENCE REQUIREMENT	MEASUREMENT REQUIREMENT	INSTRUMENT REQUIREMENTS	EXPERIMENT REQUIREMENTS
"Undertand cosmic acceleration: dark energy and inflation."—P5 Support CMB experiments as part of the core particle physics program.	Test models of inflation by measuring or putting upper limits on r, the ratio of tensor fluctuations to scalar fluctuations.	If $r = 0$: $\sigma(r) \leq 0.0005$; $r < 0.001$, 95% confidence; in four years. If $r = 0.003$: measure at equivalent 4σ; in four years (see Section 3.2).	Measure Q and U over a sufficient fraction of the sky at a sufficient set of frequencies to control foregrounds with: a) sufficient control of low ell noise and systematics and b) sufficient resolution to allow delensing. One set of measurement specifications that satisfies this is: Measure Q and U over 3% of the sky at frequencies of 20, 30, 40, 85, 95, 145, 155, 220, and 270 GHz, with Q/U-map noise levels of 14, 8.7, 8.2, 1.6, 1.3, 2.0, 2.0, 5.2, 7.1 μK-arcmin, map noise 1/ell knees of ≤60 at the six highest frequencies and ≤60 at at least one of the three lowest frequencies, and angular resolutions of ≤15 arcmin at 150 GHz, scaled by wavelength to other bands except requiring <30 arcmin at at least one of the two lowest-frequency bands. For delensing, measure the same 3% of the sky at frequencies of 30, 40, 95, 145, 220, and 270 GHz, with angular resolutions of ≤3 arcmin at 95, 145, and 220 GHz and Q/U map noise levels of 7, 7, 1.0, 1.3, 7, and 7 μK-arcmin.	One instrument configuration that satisfies the measurement requirements is: 14 0.5-meter-aperture cameras with detectors distributed as Frequency: 30, 40, 85, 95, 145, 155, 220, 270 GHz # detectors: 260, 470, 17k, 21k, 18k, 21k, 34k, 54k plus higher-resolution channels at 20, 30, and 40 GHz from the delensing survey below. For delensing, one 6-meter-aperture telescope with detectors distributed as Frequency 20, 30, 40, 95, 145, 220, 270 GHz # detectors: 130, 250, 500, 25k, 25k, 8.7k, 8.7k	Four years of observing (wall-clock time). We do not explicitly specify here many characteristics of the instruments and experiment, such as bandwidth, optical efficiency, bad pixels, weather losses, Sun constraints, and so on. These are, however, built into the simulations that calculate the measurements that will be achieved (column D) by the hardware in column E, based on actual in-the-field performance achieved by BICEP/Keck and SPT at Pole, and ACT in the Atacama, over years of observing.
"What are the properties of neutrinos?"—NWNH2010 Discover the elementary constituents of matter and energy. "Explore the unknown: new particles, interactions, and physical principles."—P5	Determine the role of light relic particles in fundamental physics, and in the structure and evolution of the Universe.	$\Delta N_{\rm eff} \leq 0.06$, 95% confidence; in seven years.	Measure I, Q, and U over a sufficient fraction of the sky at sufficiently low noise and with sufficient frequencies to control foregrounds. One set of measurement specifications that satisfies this is: Measure 40% of the sky at frequencies of 40, 95, 150, 220, and 270 GHz, with angular resolution of <=1.5 arcmin at 150 GHz, and Q/U map noise levels of <=1.3 μK-arcmin when 95 and 150 GHz are optimally combined.	One instrument configuration that satisfies the measurement requirements is: Two six-meter-aperture telescopes with detectors distributed as Frequency: 20, 30, 40, 95, 145, 220, 270 GHz # detectors: 290, 640, 1.1k, 50k, 50k, 17k, 17k	Seven years of observing (wall-clock time). See additional information in the cell above.
		$\sigma(\Sigma m\nu)$ = 25 meV (lensing or clusters), with $0.006 < \sigma(\tau) < 0.01$ and (for lensing) errors on the BAO distance ratio parameter rs/DV as given by DESI Collaboration et al (2016).	Achieved with the same measurements as required for $N_{\rm eff}$, above.		
		CMB-S4 shall be designed to maximize the galaxy cluster, neutrino, and other astrophysical and cosmological science return without increasing the project cost or compromising the performance for r and $N_{\rm eff.}$			
"Understand cosmic acceleration: dark energy and inflation."—P5	Test models of dark energy and modified gravity by measuring the growth of cosmic structure	Measure $\sigma_8(z)$ in contiguous bins spanning redshifts 0<z<3 to a precision of 1–2% per bin, with at least 2 bins at z>1.5.	Achieved with the same measurements as required for $N_{\rm eff}$, above.		
"How do baryons cycle in and out of galaxies, and what do they do while they are there?"—NWNH2010 Cosmic Dawn: Origins: The origin of galaxies and large-scale structure	Understand the impact of feedback processes on the distributions of dark and baryonic matter in the Universe	Using the kSZ and tSZ effects, measure the baryon density and thermal energy profiles of halos of mass M > 10^12.5 Msun/h to 1% at z<1 and 2% (T redshift 1 < z < 3 on scales down to rmin = 300 kpc/h (kmax = 10 h/Mpc in Fourier space).	Achieved with the same measurements as required for $N_{\rm eff}$, above.		

Requirements that determine the design of the experiment are in boxes shaded blue.
Additional science that can be done with the instrument required by the blue boxes is shown in boxes shaded green.
*P5 = Particle Physics Project Prioritization Panel