2.5 Complementarity with other Measurements and Surveys (1 pg, Lawrence? Schmidt?)

Should describe complementarity with sub-orbital CMB measurements and with other surveys, both in space and on the ground. This is summary text (more detail in subsections about specific objectives)

2.6 Foregrounds (4 pgs, Clem? Jacques? Raphael? Brandon?)

The state of knowledge and known challenges; how does PICO address the challenges; forecast of performance.

2.7 Systematic Errors (3 pgs, Crill)

A CMB mission aiming for the unprescedented sensitivity of PICO must control systematic errors to avoid bias or an increased variance of the science measurement. Systematics must be controlled or corrected to a level that enables the PICO science goals (better than 1 nanoKelvin in the map). Mitigation of systematic errors is the most important reason (along with the availability of broad wavelength coverage) to perform a measurement of the CMB polarization from a space telescope; Compared with a ground-based, sub-orbital, or even a space mission in low-Earth orbit, the L2 environment offers excellent stability as well as the ability to observe large fractions of the sky on many time scales without interference from the Sun, Earth, or Moon. This redundancy of observations allows the checking of consisitency of results and an improved ability to correct systematic errors in post-processing analysis.

During the course of the PICO Study, a systematics working group examined systematic errors affecting PICO, Most systematic errors can be mitigated by careful design and engineering of the spacecraft and instrument, and the use of present-day state-of-the-art technology and data analysis tools. However, some systematic errors may limit the precision of the B-mode measurement and the group studied these in further detail. The work was based on the experience of the group's involvement with past missions, in particular Planck, and in recent detailed studies on the CORE and LiteBird concepts

End-to-end simulation of the experiment is an essential tool, including realistic instabilities and non-idealities of the spacecraft, telescope, instrument and folding in data post-processing techniques used to mitigate the effects. Systematics are coupled with the spacecraft scan strategy, and the details of the data analysis pipeline. During the study, the PICO team used simulation and analysis tools developed for the Planck mission[1] and the CORE mission concept, adapting them for PICO. These tools allowed a deeper examination of several key systematic errors.

2.7.1 List of Systematics

The systematic errors face by PICO can be categorized into three broad categories 1) Intensity-to-polarization leakage, 2) stability, and 3) straylight. These were prioritized for further study based on the team's assessment of how well these systematics are understood by the community, whether mitigation techniques exist - either in instrument design or in data analysis.

Name	Description	State-of-the-art	Additional Possible Mitigation
Leakage			
Bandpass Mismatch	Edges and shapes of the the spectral filters vary from detector to detector. leaks T $\rightarrow$ P, P $\rightarrow$ P leakage if the source's bandpass differs from calibrator's bandpass[**?**]	Precise bandpass measurement[**?**]; SRoll algorithm[**?**]; filtering technique[**?**];	polarization modulation; full I/Q/U maps for individual detectors mitigates; additional component solution (see Banerji& Delabrouille (in prep) **Current techniques may be adequate**
Beam mismatch		See Sect. 2.7.2	
Gain mismatch			
Time Response Accuracy and Stability			
Readout Cross-talk			
Polarization Angle			See Sect. 2.7.2
Cross-polarization			
Chromatic beam shape			
Stability			
Pointing jitter			
Gain Stability			See Sect. 2.7.3
Straylight			
Far Sidelobes			See Sect. 2.7.4
Other			
Residual correlated cosmic ray hits			

Table 1: Systematic errors expected to affect PICO.

2.7.2 Absolute polarization angle calibration

...

2.7.3 Gain Stability

...

2.7.4 Far Sidelobe Pickup

...

2.7.5 Key Findings

Understanding and controlling the effects of systematic errors in a next-generation CMB probe is critical.

The raw sensitivity of the instrument should include enough margin that data subsets can independently archieve the science goals. This allows testing of the results in the data analysis and additional data cuts, if needed.

In a PICO mission's phase A, a complete end-to-end system-level simulation software facility would be developed to assist the team in setting requirements and conducting trades between subsystem requirements while realistically accounting for post-processing mitigation. Any future CMB mission is likely to have similar orbit and scan characteristics to those of PICO, thus there is an opportunity for NASA and the CMB community to invest in further development of this capability now.

3 Instrument (6 pgs, Hanany & Trangsrud)

Telescope (Hanany / Young), focal plane (Hanany / Young), cooling (Trangsrud), readout (O'Brient)