6.0 Conclusions and Recommendations

6.1 Conclusions

A first-principle, dynamic-electrothermal, end-to-end numerical model of the CERES flight sensors has been completed. This model is comprised of several sub-modules including a Monte-Carlo-based ray-trace, transient finite-difference electrical and thermal diffusion modules, and a transient finite-element thermal diffusion module. The completed model provides a virtual instrument which has been used to investigate various aspects of the performance of the actual instrument. In particular the virtual instrument allows fast inexpensive investigations into areas of instrument performance which are difficult and expensive to measure in the physical domain.

Investigations completed in this body of work include analyzing an unexpected slow response mode in the detector output, predicting the optical and instrument point spread functions of the flight sensors, predicting the end-to-end transfer function of the instrument, analyzing the effects of degrading detectors on instrument performance, and optimizing the effective field-of-view of the flight sensors.

In the arena of the slow response mode, the model was used to determine coefficients for a filtering algorithm developed by Smith [66]. The uniqueness of the model is that it easily predicts both the magnitude, 0.726 percent, and time constant, 310 ms, of the slow mode. It is not yet clear if the magnitude of the slow mode may be directly determined from experimental data. Additionally, the model was used to verify that the slow mode has no residual effects on the instrument point spread function. Prediction of the point spread function provided an independent means to determine the time lag introduced in the data due to the processes of thermal diffusion in the detectors and conditioning of the signal by the Bessel filter. This prediction yielded a time lag of 23 ms, or 1.55 deg, which is in consonance with Smith's theoretical derivation [67].

Using the model to predict the end-to-end transfer function of the flight sensors demonstrated that a corner frequency of approximately 14 Hz exists for energy impinging on the active detector. This is significantly less than the 22 Hz corner frequency of the conditioning electronics and is related to thermal difusion in the detector layers.

In optimizing the effective field-of-view, the end-to-end instrument model was mated with Villeneuve's [33] Atmospheric Radiation Model. This investigation assessed the ability of the instrument to accurately recover an effective TOA flux for nonhomogeneous Earth scenes. It was determined that the optimal effective field-of-view is defined by the topographical contour line representing the location where optical throughput has an attenuated value of 40- to 50-percent of the peak on-axis value. This attenuation is caused by the presence of spherical optics which are unable to focus incoming energy onto a point.

In addition, studies were carried out to assess how well the point spread function must be known to accurately incorporate high-resolution cloud imager data in the operational data reduction algorithms. This study demonstrated that the recovered shortwave TOA flux was five times more sensitive to point spread function weighting of cloud imager data than the longwave TOA flux for the datasets studied. This discrepancy was anticipated since shortwave flux is much more sensitive to the presence of clouds than longwave flux.

6.2 Recommendations

Although the current effort has culminated in the completion of an end-to-end model for the CERES flight sensors, a plethora of work remains. The model is currently tailored to the total channel of the CERES PFM instrument. Over the life of the CERES project it is anticipated that more than 15 sensors on five different flight models will be placed in orbit. Each sensor has slightly different performance characteristics due to allowable tolerances during fabrication. Tailored versions of the model should be created for each channel which will make it into orbit, since the strength of the models is that they can readily account for these fabrication tolerances. A constrained optimization methodology is recommended to facilitate this process.

Further research should be done in the area of weighting cloud imager data by the instrument point spread function. The current effort has only bounded the problem by looking at two extreme weightings. Sensitivities to realistic variations in weightings should also be completed for a statistically significant number of data sets. This should involve using the end-to-end model to scan simulated Earth scenes provided by Villeneuve's Atmospheric Radiative Transfer model. The benefit of completing this work numerically is that by definition one knows *a priori* the true TOA flux. This work should be done in consonance with validation efforts which the CERES Science Team will be conducting independently.

Finally, further work should be conducted in the area of creating autoregressive models for remote sensing instruments. Although the study reported here was not successful, the autoregression method appears promising. The use of autoregressive models to analyze data product is a concept which should be taken into account during the design process of future instruments. Knowledge of the methods to be employed in analyzing data product may drive the design of signal conditioning electronics as well as field-of-view and sampling rates and must be considered to optimize the final design.