Title of Grant / Cooperative Agreement:	Continuing CIMSS Participation in VIIRS FU-1 Test Program, Data Evaluation and Review in Support of the NASA NPP Government Team
Type of Report:	Summary of Research
Name of Principal Investigator:	Chris Moeller
Period Covered by Report:	10/1/2009 - 3/31/2014
Name and Address of recipient's institution:	University of Wisconsin, 21 N. Park St, Suite 6401, Madison, WI 53715-1218
NASA Grant / Cooperative Agreement Number:	NNX09AP55G

Reference 14 CFR § 1260.28 Patent Rights *(abbreviated below)*
The Recipient shall include a list of any Subject Inventions required to be disclosed during the preceding year in the performance report, technical report, or renewal proposal. A complete list (or a negative statement) for the entire award period shall be included in the summary of research.

Subject inventions include any new process, machine, manufacture, or composition of matter, including software, and improvements to, or new applications of, existing processes, machines, manufactures, and compositions of matter, including software.

Have any Subject Inventions / New Technology Items resulted from work performed under this Grant / Cooperative Agreement?	No ◉	Yes ○
If yes a complete listing should be provided here: Details can be provided in the body of the Summary of Research report.		

Reference 14 CFR § 1260.27 Equipment and Other Property (abbreviated below)
A Final Inventory Report of Federally Owned Property, including equipment where title was taken by the Government, will be submitted by the Recipient no later than 60 days after the expiration date of the grant. Negative responses for Final Inventory Reports are required.

Is there any Federally Owned Property, either Government Furnished or Grantee Acquired, in the custody of the Recipient?	No ◉	Yes ○
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Attach the Summary of Research text behind this cover sheet.

Reference 14 CFR § 1260.22 Technical publications and reports (December 2003)
Reports shall be in the English language, informal in nature, and ordinarily not exceed three pages (not counting bibliographies, abstracts, and lists of other media).

A Summary of Research (or Educational Activity Report in the case of Education Grants) is due within 90 days after the expiration date of the grant, regardless of whether or not support is continued under another grant. This report shall be a comprehensive summary of significant accomplishments during the duration of the grant.

Continuing CIMSS Participation in VIIRS FU-1 Test Program, Data Evaluation and Review in Support of the NASA NPP Government Team

Final Report on NASA Award NNX09AP55G
Covering the period Oct 1, 2009 – March 31, 2014
Chris Moeller, Dan LaPorte, Paul Menzel
CIMSS at the University of Wisconsin - Madison

1) INTRODUCTION

Award NNX09AP55G to the University of Wisconsin covers the period Oct 1, 2009 – March 31, 2014. This document represents the final report on this project. The award has supported activities of the F1 and J1 (JPSS-1) VIIRS sensor development and pre-launch testing (partial only for J1) as well as ~2.5 years of on-orbit service for the SNPP VIIRS (formerly F1 VIIRS) with a focus on spectral and radiometric aspects of VIIRS performance. The award has also supported continuous participation on the VIIRS Government team, now the VIIRS SDR Team.

2) PROGRESS

2.1 Highlights of Progress in Years 1-4

Funding under this project has supported participation in elements of the VIIRS F1 prelaunch evaluation and characterization, the VIIRS J1 test program preparation and onset, and the SNPP (F1) VIIRS post-launch performance evaluation. Highlights of this participation includes:

- Evaluation of F1 VIIRS sensor level TVAC test data (Raytheon El Segundo) with a heavy focus on spectral as well as cross talk and radiometric characterizations.
- On-site participation in the Spacecraft level ambient test program at Ball Aerospace in Boulder, CO, including special spectral test process, data collection, analysis, and review.
- The analysis, review, documentation and distribution of Govt Team "Best" RSR for F1.
- Review and approval of at-launch Northrop-Grumman RSR for F1.
- On-orbit update of SNPP at-launch RSR using improved RSR analysis.
- Investigation and review of RTA mirror degradation and its impact on SNPP RSR.
- SNPP Modulated RSR impact on TOA radiance of VIIRS bands.
- Cross talk impact assessment on F1 VIIRS VisNIR band SDR and VIIRS cloud EDRs.
- Development and implementation of F1 VIIRS task network tools.
- SNPP VIIRS TEB performance evaluation studies including VIIRS scene temperature dependent biases and dependence on OBC operating temperature.
- Supported upgrades and refurbishment of the SpMA GSE for the J1 test program.
- Recommendations for the J1 test program, including the FP-15, -16 test procedure/setup.

These highlights have been discussed in detail in the annual reports for years 1-4 of this project and will not be repeated here.

The significant findings of years 1-4 are as follows:

A) SNPP VIIRS on-orbit spectral characterization is mature.

The SNPP VIIRS at-launch spectral calibration has been updated twice since launch. The initial update (May 2012) incorporated improved knowledge of the VisNIR RSR by including the final pre-launch analysis of spacecraft level tests (incomplete at time of Mx5.0 release). A second update (April 2013) adjusted the VisNIR and SWIR band RSR for modulation due to the RTA mirror degradation anomaly.

B) SNPP VIIRS TEB RVS characterization is performing within requirements.
VIIRS-CrIS comparisons stratified by sensor view angle (RAD-04) show < 0.1 K dependence on sensor viewing angle for bands M13, M15, and M16. This result is consistent throughout the period of record of SNPP and suggests that the HAM mirror RVS is well characterized in TEB wavelengths.

C) Impact of RTA degradation on SNPP VIIRS RSR was mitigated by an RSR update.
RTA mirror degradation anomaly had a clear and predictable impact on VIIRS VisNIR and SWIR band spectral calibration. This effect was estimated at about 0.5% in simulated VIIRS M1 observations. This has been mitigated by an RSR update (item A) using a snapshot RSR for Feb 1, 2013. It is estimated that ~70% of the expected RTA mirror degradation has taken place by Feb 1, 2013 and therefore future updates of RSR for ongoing RTA mirror degradation are not anticipated.

D) SNPP VIIRS band M15 contains small scene temperature dependence in its bias.
VIIRS and CrIS comparisons (RAD-12A) show a small but systematic scene temperature dependent bias in M15. Adjustment to the CrIS radiometric calibration for Mx8.1 have reduced this bias down to about 0.2 K at cold scenes. Remaining temperature dependent bias may be contained in the VIIRS C0 offset coefficient.

E) SNPP VIIRS TEB calibration carries a small dependence on OBC operating temperature
VIIRS comparisons to CrIS (RAD-12A) during VIIRS WUCD events have demonstrated that VIIRS calibration has a small (~0.1 K) spectrally dependent response to changing the OBC temperature. The dependence is exhibited by biases for bands M13, M15 and M16 all converging near zero bias when the VIIRS OBC is allowed to settle at ambient temperature. This behavior suggests that some element of the calibration is not ideally characterized and is changing as a result of the VIIRS OBC temperature change. This behavior has been consistent since launch.

F) SNPP VIIRS TEB SDR radiance accuracy found to be compliant with requirements.
Comparisons between VIIRS and CrIS (RAD-12A) and IASI (RAD-12B) as well as between VIIRS and the airborne SHIS instrument (RAD-21) indicate that VIIRS is performing within the radiometric uncertainty requirement in all TEB and at all scene temperatures (despite small systematic bias behavior). The SHIS comparisons are for warm scenes only but include the additional element of a NIST traceable source.

G) On-orbit drift in SNPP VIIRS TEB SDR is found to be very small, < 50 mK/yr.
VIIRS TEB comparisons to CrIS from March 2012-September 2013 show minimal seasonal dependence and drift over time. The stability of the sensor is exceptional and will continue to be monitored throughout its lifetime.

Further details of these findings along with other elements of VIIRS performance are available in the annual reports for years 1-4 of this project. These findings have contributed to the body of evidence that SNPP VIIRS SDR is currently (and can be expected to continue) performing at a validated quality status level.

2.2 Recent J-1 VIIRS Test Program Progress

During the final 6 month period of this project, the J1 ambient phase test program was underway (Aug 2013 – Jan 2014). Under this project, reviews of performance testing on polarization (FP-11) and HAM RVS (FP-10) were conducted along with reviews of functional testing. Important findings include:

- Polarization is non-compliant for bands M1-M4. The source of the polarization appears to be in the IFA (filters), resulting in an apparent small dependence of the RSR on polarization, primarily near the edges of the extended bandpass zone. A Raytheon polarization model matches the behavior well and is a source of possible insight on SDR impact for the Govt team.
- FP-10 HAM RVS characterization appears to meet the 0.3% uncertainty requirement for all bands although detector 4 of band I3 is out-of-family with other detectors. Band M9 is marginally compliant owing to the influence of ambient water vapor on the measurements. Initial attempts by Raytheon to remove the water vapor influence did not result in marked improvement. Band I5 shows a few detectors exceeding the 0.3% requirement.
- A review of the temperature and relative humidity data collected to characterize the ambient water vapor during FP-10 P1 (RSB) testing shows unexpected behavior for a portion of the data collection, possibly due to external influences (frequency based noise?) within the test environment. Wisconsin is working with Raytheon to effectively model and remove the water vapor influence on the FP-10 P1 M9 measurements.

2.3 SpMA Upgrades Update

Upgrades to the SpMA have largely been completed and final adjustments to the FP-15 and FP-16 test plans are being discussed. A recommendation for concurrent measurements of RSO with RSR for FP-16 VisNIR bands and FP-15 DNB has been made to Raytheon and is currently in negotiation. Concurrent measurements of RSO with RSR will mitigate possible loss of RSO knowledge requiring retesting if/when source bulbs fail. This occurred several times during the F1 test program. Concurrent RSO measurements also capture any drift in the source bulb output over time; source drift was known to exist during the F1 test program. An increase in the frequency of offline RSO measurements is also being considered as a satisfactory alternative. Raytheon has also proposed several practices to minimize the likelihood and impact of source bulb failure, including bulb voltage monitoring, pre-deployment “burning in” of spare bulbs, and planned replacement of source bulbs before burnout after a TBD number of hours of usage. Wisconsin supports these practices for J1 spectral testing.

2.4 NIST T-SIRCUS Use in J-1 Test Program

Interest remains high in the deployment of the NIST T-SIRCUS system to make RSR measurements for J1 VisNIR bands. The unpolarized T-SIRCUS source will provide measurement-based insight into the polarization influence on VisNIR bands. The T-SIRCUS setup (flood illumination of VIIRS focal plane) also measures all spectral influences simultaneously on the RSR including in-band, out-of-band, optical and electronic cross talk, correctly scaling these influences by virtue of the integrated flight-like measurement. It is recommended that the T-SIRCUS system be deployed to Raytheon for spectral measurements before the VIIRS is shipped to Ball Aerospace.

2.5 J-1 Bandpass Separation Specification

A low level specification on bandpass overlap between bands was reviewed for J1 application. The spec mandates that there will be no more than 5% overlap of extended bandpass regions of adjacent bands. The spec supports spectral separation between the VIIRS split window SST bands M15 and M16, preserving the water vapor absorption differential between these bands. The spec will be retained for J1 compliance. A review of F1 RSR shows that spectral performance was marginally compliant with this spec.

3) CONFERENCES and PUBLICATIONS

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