GOES-R and JPSS Proving Ground Demonstration Proposal:
Hazardous Weather Testbed – 2019 Spring Experiment

1. **Project Title:** 2019 Geostationary Operational Environmental Satellite R-series (GOES-R) and Joint Polar Satellite System (JPSS) Proving Ground – Hazardous Weather Testbed (HWT) Experimental Warning Program (EWP) Product Demonstrations

2. **Organization**: HWT/EWP, Norman, OK

3. **Products to be Demonstrated as a GOES-R and JPSS Proving Ground activity at the HWT in 2019:**
    - **a.** GOES-16 Advanced Baseline Imager (ABI) Imagery, Band Differences, RGB's, and Baseline Derived Products (GOES-R Baseline)
    - **b.** GOES-16 Geostationary Lightning Mapper (GLM) Total Lightning Data (GOES-R Baseline)
    - **c.** GOES-16 Advanced Baseline Imager (ABI) All-sky Total Precipitable Water (TPW), Layer Precipitable Water (LPW), and Derived Atmospheric Stability Indices (Risk Reduction)
    - **d.** ProbSevere Model (Risk Reduction)
    - **e.** NOAA Unique Combined Atmospheric Processing System (NUCAPS) Temperature and Moisture Profiles and Products (JPSS Baseline)
    - **f.** Advanced Blended Total Precipitable Water Product (Risk Reduction)

4. **Demonstration Project Summary:**
    - **a. Overview:** As a GOES-R and JPSS Proving Ground (herein, Satellite Proving Ground) activity, GOES-R series and JPSS (via Suomi NPP and NOAA-20) products and capabilities will be demonstrated in the HWT during the 2019 Spring Experiment. Satellite Proving Ground activities during the Spring Experiment will take place during the weeks of April 22, April 29, May 6, May 13, May 20, and June 3 2019 in the EWP. The EWP provides a conceptual framework and a physical space to foster collaboration between research and operations to test and evaluate new and emerging technologies and science to advance National Weather Service (NWS) warning operations. Products will be demonstrated within a simulated warning operations environment using a real-time AWIPS-II (D2D) framework within the HWT. NWS forecasters and broadcast meteorologists will be the primary evaluators. Various project scientists will also be in attendance throughout the experiment to provide project expertise and to communicate directly with the user community. The exposure to appropriate GOES-R series and JPSS products and capabilities during the height of the spring severe weather season will provide NWS forecasters, broadcast meteorologists, and scientists an opportunity to help determine best practices and operational applicability as well as critique and suggest improvements for algorithms in different stages of their development cycle. For the 2019 Spring Experiment, live GOES-16/17 imagery and products will once again be evaluated along with experimental GOES-R and JPSS algorithms.

b. Plan, Purpose, and Scope: The HWT provides the Satellite Proving Ground with an opportunity to demonstrate Baseline, Future Capabilities, and experimental products associated with the next-generation GOES-R series geostationary and JPSS polar satellite systems that have the potential to improve short-range hazardous weather forecasting, nowcasting and warnings. It will allow forecasters to test and develop best practices for using GOES-R data in convective situations, and will gauge the effectiveness of the NWS wide satellite training. Additionally, the Satellite Proving Ground demonstrations in the HWT will be combined with another demonstration testing some new severe weather radar algorithms and products. This will allow a more thorough evaluation of products in both experiments, with more forecasters looking at the data in real time. The structure of Satellite Proving Ground activities at the 2019 Spring Experiment in the HWT/EWP will be as follows.

There will be a total of approximately 36 external participants spanning the six weeks, with six participants in attendance each week. Forecasters will work in pairs participating in real-time simulated short-term forecast and warning operations in County Warning Areas (CWAs) across the CONUS determined based on SPC convective outlooks where convection is anticipated throughout the day. Using the GOES-R HWT blog, participants will document their short-term experimental mesoscale forecast updates in real-time, highlighting the impact of the satellite-based imagery and products on those testbed forecasts. Additionally on the blog, they will record the reasoning behind experimental warnings, which will be issued using AWIPS-II/WarnGen, focusing on how the satellite information influenced those decisions. Participants will be encouraged to provide updates (verification) on the performance of previous experimental issuances using the blog as well.

Each week will begin with an 11 am - 7 pm orientation/forecast shift on Monday, while the Tuesday through Thursday eight hour forecast shifts will begin between 9 am and 3 pm, depending on when the primary convective activity is likely to start. The goal will be to begin Tuesday through Thursday two to three hours before the onset of deep convective development so data can be tested in the pre-convective environment as well as post-convective initiation. Each Mon-Thurs forecast shift will begin with a brief discussion regarding the anticipated convective threat (location/timing/mode/severe type) for the day. At the end of the day on Thursday, participants will develop presentations sharing their experiences in the Spring Experiment, highlighting appropriate cases and satellite products. These will be presented virtually Friday morning as part of the “Tales from the Testbed” webinar for at least a few of the weeks, in which scientists and NWS entities outside of Norman are encouraged to participate.

Participants will receive training beforehand in the form of Articulate Power Point modules to be completed for the non-operational and JPSS products being demonstrated, along with supplemental GLM training. Broadcast participants are strongly encouraged to visit their local NWS Forecast Office for AWIPS-II hands-on familiarization prior to the experiment. Feedback will be gathered throughout the experiment in the form of: 1) surveys to be completed at the end of each day and

week, 2) real-time blogging, 3) real-time discussions, 4) daily debriefs during the start of each day, and 5) weekly debriefs Friday morning. Notes from the daily and weekly debriefs will also be posted to the GOES-R HWT blog (http://goesrhwt.blogspot.com/).

c. **Goals:** The main objective of the Satellite Proving Ground demonstrations within the HWT is to demonstrate and evaluate Baseline, Future Capability and experimental products that have the potential to improve short-term forecasts, nowcasts and warnings of hazardous weather across the CONUS. Highlights of forecaster feedback will be organized in a final report which will be submitted to the Satellite Proving Ground and provided to product developers so that recommended changes and improvements to products can be addressed. The one-on-one interactions between the project scientists, NWS forecasters, and broadcast meteorologists allow for valuable discussions during real-time hazardous weather events, maximizing research-to-operations-to-research (R2O2R) feedback, a key goal of the Proving Ground. Additionaly, the real-time demonstration of experimental and baseline products ensures the algorithms work properly in AWIPS-II. Finally, exposing NWS forecasters and broadcast meteorologists to GOES-R series baseline products and capabilities shortly after availability allows for the development of best practices for using the data in severe weather operations.

5. **Participants Involved:**
   a. **Providers:**
      i. GOES-16 Advanced Baseline Imager (ABI) Imagery, Band Differences, RGB's, and Baseline Derived Products (Bowlan – CIMMS/SPC)
      ii. GOES-16 Geostationary Lightning Mapper (GLM) Total Lightning Data (Calhoun – CIMMS/NSSL)
      iii. GOES-16 Advanced Baseline Imager (ABI) All-sky Total Precipitable Water (TPW), Layer Precipitable Water (LPW), and Derived Atmospheric Stability Indices (Li – CIMSS)
      iv. ProbSevere Model (Pavolonis – NESDIS)
      v. NOAA Unique Combined Atmospheric Processing System (NUCAPS) Temperature and Moisture Profiles (Barnet – STC)
      vi. Advanced Blended TPW with GOES-R (Forsythe – CIRA)
   b. **Consumers:**
      i. Hazardous Weather Testbed

6. **Project Schedule/Duration (some dates are preliminary and subject to change):**
   a. Products tested in HWT AWIPS-II system: 29 March 2019
   b. Training sent to participants: 25 March 2019
   c. Product demonstrations begin: 22 April 2019
   d. Product demonstrations end: 7 June 2019

7. **Project Decision Points and Deliverables:**
   a. Proving Ground Operations Plan – First Draft: 4 March 2019
   b. Proving Ground Final Report: 30 August 2019

8. **Responsibilities and Coordination:**
    - **a.** Michael Bowlan, OU/CIMMS and NOAA/SPC – Co-Principal Investigator for Satellite Proving Ground activities taking place in the HWT in 2019
    - **b.** Kristin Calhoun, OU/CIMMS and NSSL – Co-Principal Investigator for Satellite Proving Ground activities taking place in the HWT in 2019
    - **c.** Kodi Berry, OU/CIMMS – EWP Coordinator

9. **Budget and Resource Estimate:** Funded through the GOES-R and JPSS Science Offices as part of the Omnibus Proving Ground funding to CIRA, CIMSS, UAH, and NASA/SPoRT.

Product Name: GOES-R series Advanced Baseline Imager (ABI) Imagery, Band Differences, RGB's, and Baseline Derived Products

Primary Investigator: Michael Bowlan (CIMMS/SPC)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- GOES-16/17 ABI imagery and products provide information about the pre-convective environment, convective initiation, and the evolution of mature convection.
- Evaluation of GOES-16/17 ABI imagery and products in the HWT shortly after availability in AWIPS allows for the development of best practices for use in convective situations.

Product Overview:

- GOES-16/17 ABI single-band imagery and band differences are already available to NWS forecasters in AWIPS-II.
- RGB imagery and baseline derived products are also already available to NWS forecasters in AWIPS-II.
- Imagery and products idenitified as potentially benifiting forecasters in convective warning situations will be the focus of this evaluation.
- 30-sec and 1-min imagery will be evaluated when available, in addition to the 5-min CONUS imagery

GOES-16/17 ABI Products:

- ABI single-band imagery (16 channels)
- ABI baseline derived products
    - Derived Motion Winds, Derived Stability Indices, Total Precipitable Water, etc.
- ABI band difference imagery
    - 10.3 – 12.3 um (Split Window) and others depending on situation
- ABI RGB imagery
    - Simple: Day Cloud Convection, Day Cloud Phase Distinction, others
    - Advanced: Day Convection, Air Mass, Differential Water Vapor

Concept for Operational Demonstration:

- GOES-16/17 ABI imagery and products will be delivered to the HWT via the Satellite Broadcast Network (SBN) and displayed in AWIPS-II.

Concept for Operations:

- GOES-16/17 ABI imagery and products are centrally produced at OSPO/ESPC and delivered by SBN and PDA.

Product Name: Geostationary Lightning Mapper (GLM) and derived lightning detection products

Primary Investigator: Kristin Calhoun (OU/CIMMS & NOAA/NSSL)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Identify developing deep convection and areal coverage by observing optical detections of both cloud-to-ground and intra-cloud lightning.
- Understand differences between the various products for different severe weather scenarios, including early, rapidly growing convection versus mature severe convection.
- Evaluate trends from GLM in relationship to storm evolution, storm coverage, severe weather, and flooding potential along with relationships to other fields available at HWT.
- Identify product types, visualization techniques, and tools for future GLM observations.
- Identify best practices for GLM products and integration into forecaster storm interrogation methodology from both GOES-16 and GOES-17.

Product Overview:

- GLM Level 2 data are geolocated points of lightning flashes, groups and events derived from the Lightning Cluster Filter Algorithm (LCFA). Flashes are a cluster of all groups falling within a 330 ms, 16.5 km window.
- GLM gridded products are a reconstruction of the imagery from those point detections, providing a spatial footprint of those flashes.
- The gridded GLM products are currently being created to match the CONUS ABI grid that is an oversampled (nominal 2 km pixels), anti-aliased remapping of the GLM CCD.
- Time period of display will be evaluated as part of the experiment, but nominally will be 1-min and 5-min Flash Extent Density, Average Flash Area, Total Optical Energy.
- Feedback has shown that meteorological signals are more apparent in the gridded imagery than in the point detections.

GOES-16 GLM Products:

- GLM Flash Extent Density (1 min, 5 min) – an accumulation of the number of flashes that pass through a given location.
- GLM Average Flash Area (1 min, 5 min) – the average area of all the flashes that illuminate a given location in the time window.
- GLM Total Optical Energy (1 min, 5 min) - constructed from the energy of each event and spread uniformly across each event footprint. May be interpreted as the total light detected by the GLM at a given location.

Concept for Operational Demonstration:

- GLM L2 data is be delivered to the HWT via the SBN, the gridded products are created locally by NSSL and also received via LDM in collaboration with the NWS Proving Ground. The gridded data are displayed in AWIPS-II.

Concept for Operations:

- GLM gridded data are expected nationwide via the SBN by late spring/early summer 2019. The choice of additional products will be a function of HWT and NWS Proving Ground Feedback.

Product Name: GOES-16 derived all-sky Total Precipitable Water (TPW), Layered Precipitable Water (LPW), and Derived Atmospheric Stability Indices new products

Primary Investigator: Jun Li (CIMSS)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Provides all-sky, observation-based details about the recent evolution of moisture and instability in the atmosphere, important factors during pre-storm mesoscale analysis.
- Ability to increase forecaster confidence regarding the state of the current thermodynamic environment will be assessed.
- This demonstration will help enhance the utilization of GOES-R series high spatial and temporal resolution ABI atmospheric products in situation awareness and nowcasting.

Product Overview:

- The blended product is a combination of three parts resulting in a single, all-sky product: GOES-R series LAP baseline algorithm for clear-skies, GOES-R Risk Reduction algorithm for some cloudy-skies, GFS NWP model for overcast skies.
- GOES-16 products for full-CONUS coverage with 6 km resolution (note that baseline LAP is 10 km resolution).
- Various thermodynamic fields are computed, including: TPW, LPW, CAPE, and LI
- The product updates 30-minutes, shortly after the GOES-16 ABI L1B data are available.

Product Methodologies:

- GOES-16 ABI L1B data are processed through the GOES-R series LAP retrieval algorithms for both clear and cloudy skies.
- GOES-R series cloud mask algorithm is implemented for GOES-16 ABI clear field-of-view (FOV) detection.
- Cloudy sky retrieval algorithm allows for products under some cloudy sky conditions (GOES-R3 algorithm).
- TPW, LPW, and various Stability Indices are derived from the GOES-16 ABI with GOES-R series LAP retrieval algorithms.
- GFS NWP information is used where data gaps (overcast and failed retrievals) still exist with modification to reduce discontinuation between GFS and retrievals.

All-sky LAP Products:

- GOES-16 ABI all-sky TPW, LPW, CAPE, LI

Concept for Operational Demonstration:

- GOES-16 all-sky LAP products will be delivered to the HWT via the LDM and formatted for display in AWIPS-II.

Concept for Operations:

- All-sky LAP products from GOES-R series can be produced and delivered in near real-time (NRT) for applications.

Product Name: NOAA/CIMSS ProbSevere System (ProbSevere) with associated hazard models (ProbSevere, ProbHail, ProbWind, and ProbTor)

Primary Investigator: Mike Pavolonis (NESDIS)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Assist forecasters in severe weather situations by highlighting storms that are more or less likely to become severe/tornadic in the near future.
- Products will be evaluated on their ability to increase forecaster confidence and skillfully extend lead-time to severe hazards for NWS warnings during potential severe weather situations.

Product Overview:

- Statistical models provide probabilistic guidance to forecasters on the likelihood of severe weather occurrence for convection in the near term [0-90 min].
- Algorithms incorporate multiple datasets from satellite, radar, total lightning, and NWP into easy-to-interpret products, helping to consolidate/reduce the "fire hose" of data during busy severe weather situations.
- Model output is CONUS-wide and day/night independent.

Product Methodology:

- Spatial and temporal features are extracted and computed from the satellite and radar storm objects. Satellite trends are shared with overlapping radar objects.
- Trained statistical models compute the probability that a storm will produce severe weather in the near-term, using GOES-derived, NEXRAD-derived, Earth Networks Total Lightning Network™ (ENTLN)-derived, and Rapid Refresh (RAP)-derived data.
- ProbSevere, ProbHail, ProbWind, and ProbTor update every 2 minutes. Forecasters can display each model separately in AWIPS2.

ProbSevere Products:

- ProbHail: provides guidance on severe hail.
- ProbWind: provides guidance on severe convective straight-line wind.
- ProbTor: provides guidance on tornado threats.
- ProbSevere: All-in-one display, providing guidance on the above hazards.
- Products are displayed as color contours of severe hail, severe wind, and tornado probabilities around storms on radar.
- Data readout is available by sampling the probability contour. This provides the exact probabilities of hazards and detailed model predictor values.

Concept for Operational Demonstration:

- GeoJSON files (on the order of kilobytes) will be delivered to the HWT via the LDM and converted on-the-fly into a shapefile using AWIPS-II.

Concept for Operations:

- The ProbSevere model (v1.0, evaluated in HWT in 2016) is being implemented into operations in 2020. The primary users will be radar/warning operators and mesoscale analysts in NWS WFOs. Follow-up upgrades will include ProbTor, ProbHail, and ProbWind, pending forecaster feedback.

Product Name: NOAA Unique Combined Atmospheric Processing System (NUCAPS)

Primary Investigator: Chris Barnet (Science and Technology Corporation, Columbia, MD)

Hazardous Weather Testbed, Experimental Warning Program Relevance:
NUCAPS supplements the sparse radiosonde network with wide swaths of model-independent soundings from multiple satellites at multiple times during the day. With an early afternoon orbit, NUCAPS from both SNPP and NOAA-20 has in the past proven to be useful, and modification of the lowest layer and advecting retrievals forward in time could increase the application of NUCAPS to fast changing pre-convective environments.

Product Overview:

- *For the first time*: NUCAPS profiles are available over the CONUS from TWO satellite platforms in the early afternoon: Suomi-NPP and NOAA-20. This will give forecasters complete spatial coverage over CONUS (no gaps between overpasses) and two sequential overpasses can show how atmospheric instabilities evolve in time.
- NUCAPS temperature and moisture fields can be viewed as skew-Ts, 2-D planar surfaces at specific pressure levels, or user-defined vertical cross sections. Quality control is indicated as green (good) and yellow/red (failed).
- NUCAPS retrievals with automated boundary layer modification: this year the algorithm uses a different strategy for collecting GOES and RTMA data, and tests a bulk transfer coefficient of heat that varies in space and (slowly) in time.
- An experimental NUCAPS product advected forward in time (NUCAPS-ADV) and reported every 30 minutes up to 4 hours will be tested for the first time. In clear and partly cloudy areas of the pre-convective environment, changes in CAPE and CIN should be observed with some differentiation by severe weather produced (Kalmus et al., 2019, Mon. Wea. Rev., in press) and potentially by storm mode.

Product Methodology:

- Product uses a combination of regression-based and physical retrieval algorithms to combine infrared and microwave measurements to produce vertical profiles of temperature and moisture in both clear and partly cloudy scenes.
- An automated-modification algorithm uses GOES data and RTMA surface values to improve uncertainty in the boundary layer of NUCAPS profiles.
- NUCAPS-ADV is constructed from the NOAA HYSPLIT trajectory model forced by 3-km High-Resolution Rapid Refresh (HRRR) wind fields to move air parcels adiabatically at all vertical levels and recombines into new soundings every 30 minutes.

NUCAPS Products:

- Vertical temperature and moisture profiles with/without GOES/RTMA modification
- Gridded temperature, moisture, and derived values (CAPE, lapse rate, etc.)
- Advected NUCAPS soundings and/or plan-view surfaces

Concept for Operational Demonstration:

- Reduced latency version (including CIRA's modified soundings) is from University of Wisconsin DB/CSPP and provided via LDM via NASA/SPoRT (modified via CIRA).
- Gridded NUCAPS is produced at NASA/SPoRT using data from University of Wisconsin DB/CSPP and is provided via LDM.
- Advected NUCAPS retrievals developed by JPL are processed at NASA/SPoRT using data from University of Wisconsin DB/CSPP and is provided via LDM.

Product Name: Advanced Blended TPW with GOES-R (ATPW) – Version 1.0

Primary Investigator: John Forsythe (CIRA, Colorado State University)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- The NOAA operational Blended Total Precipitable Water (BTPW) product provides hourly fields of TPW derived from polar orbiter microwave retrievals and surface-based Global Positioning System (GPS) measurements. GOES-16 data is not currently used in the operational product.
- BTPW is widely used throughout NWS as an observationally-driven analysis of TPW. But it is not advected to a common time, polar orbiter swath time varies across the grid.
- TPW is a useful variable for diagnosing Gulf moisture return and the location of dry lines, which are important for severe weather forecasting.
- GOES-R TPW has increased spatial and temporal coverage over previous GOES sensors.
- This evaluation will explore this question:

  Is a new advected TPW (ATPW), using advected polar orbiting microwave retrievals with GOES-16 TPW overlaid in clear regions, an improvement over the operational bTPW for severe weather forecasting?
- It is expected that forecasters will also compare the products to model TPW fields and other satellite-based TPW products.

Product Overview:

- Advanced TPW with GOES-16 will be provided at the same spatial and temporal resolution (hourly, near-global, 16 km resolution at equator) as the NOAA operational blended TPW.
- BTPW has no forecast model dependency. ATPW uses GFS model winds to advect passive microwave retrievals and the GOES-16 component uses GFS in its TPW solution.

Product Methodology

- The polar orbiting component of ATPW is advected to the top of each hour, using the methodology of Wimmers and Velden (2011, JAMC).
- GOES-16 TPW is overlaid onto the microwave-derived TPW grid in clear areas.

ATPW Version 1.0 Product:

- Hourly, gridded field of TPW on same map projection as operational BTPW.
  - Updated every hour, at ~:20 past hour
  - CONUS sector GOES-16 TPW used

Concept for Operational Demonstration:

- Version 1.0 ATPW with GOES-16 will be delivered to the HWT in AWIPS-2 (netCDF) format via LDM.

Concept for Operations:

- ATPW Version 1.0 will be produced at CIRA.