GOES-R and JPSS Proving Ground Demonstration Proposal:
Hazardous Weather Testbed – 2022 Spring Experiment

1. **Project Title**: 2022 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 2022:**
    a. Geostationary Lightning Mapper (GLM)
    b. NOAA Unique Combined Atmospheric Processing System (NUCAPS)
    c. Optical Flow Winds
    d. Polar Hyperspectral Soundings with Microwave and ABI data (PHSnMWnABI)
    e. NOAA/CIMSS ProbSevere v3 (ProbSevere) with associated hazard models (probSevere, ProbHail, ProbWind, and ProbTor)
    f. NOAA/CIMSS ProbSevere LightningCast

4. **Demonstration Project Summary:**
    a. **Overview:** As a GOES-R and JPSS Proving Ground (herein, Satellite Proving Ground) activity, GOES-R/JPSS products and capabilities will be demonstrated in the HWT during the 2022 Spring Experiment. Satellite Proving Ground activities during the Spring Experiment will take place during the weeks of May 23-27, June 6-10, and June 13-17 in the EWP. The EWP provides a conceptual framework and a 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 real-time, cloud-based AWIPS-II (D2D) instances hosted by Amazon Web Services (AWS). NWS forecasters will be the primary evaluators. Various project scientists and subject matter experts 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 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 2022 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, decision support services (DSS), and warnings.

Additionally, the testbed allows forecasters to test and develop best practices for using GOES-R/JPSS data in convective situations, and will gauge the effectiveness of the NWS-wide satellite training. The structure of Satellite Proving Ground activities at the 2022 Spring Experiment in the HWT/EWP will be as follows.

Approximately 24 participants will be involved in the 2022 Satellite Proving Ground, with 8 forecasters in attendance each week. Participants will receive training beforehand in the form of product user guides, PowerPoint slides, and online learning modules for the products being demonstrated. Each week will begin with a short overview of the evaluated products by subject matter experts, forecaster expectations for the week, introducing the HWT blog, and familiarizing participants with the AWIPS cloud instances. Each day will begin at 1 pm CDT, such that the participants have sufficient time to evaluate products for pre- and post-convection initiation environments.

After a brief discussion of the day's anticipated convective threat (location/timing/mode/hazards), forecasters will work in pairs of 2 or 3 with real-time simulated short-term forecasts, warning operations, and decision support services (DSS) in County Warning Areas (CWAs) across the CONUS. If little to no convection of interest is expected across the CONUS, archived cases may be used. Using the GOES-R HWT blog, participants will document their short-term experimental mesoscale forecast updates in real-time, highlight the impact of satellite-based imagery on these short-term forecasts, and provide verification on the quality of experimental products and the forecasts they produce. Warnings and advisories will be issued using AWIPS-II/WarnGen, with forecasters providing the motivation for their warnings, advisories, and DSS in a separate form. Additionally, forecasters will have the ability to create graphical forecast images to highlight how NWS forecasters can communicate hazardous weather information to the public using the demonstrated products.

Each day will end at 6 pm CDT following a short discussion period between participants and subject matter experts. 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) daily and weekly forecaster debriefs, 4) real-time discussions during operations, 5) submitted warnings, advisories, and DSS guidance, and 6) graphical forecasts. The final day of the week will consist of participants completing the end-of-week survey, followed by a two-hour final discussion period to summarize the week's activities, feedback, and recommendations.

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 and NWS forecasters 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. Additionally, the real-time demonstration of experimental and baseline products ensures the algorithms work properly in AWIPS-II. Finally, exposing NWS forecasters to GOES-R series and JPSS 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 Geostationary Lightning Mapper (GLM) (Calhoun – NSSL)
        ii. NOAA Unique Combined Atmospheric Processing System (NUCAPS) Temperature and Moisture Profiles (Esmaili – STC)
        iii. Optical Flow Winds (Rabin – NOAA/NSSL)
        iv. Polar Hyperspectral Soundings with Microwave and ABI data (PHSnMWnABI) (Bill Smith – UW, Qi Zhang – HU , Scott Lindstrom – UW)
        v. ProbSevere Hazards Model (Pavolonis – NESDIS)
        vi. ProbSevere LightningCast (Pavolonis – NESDIS)
    b. **Consumers:**
        i. Hazardous Weather Testbed

6. **Project Schedule/Duration**:
    a. Training sent to participants: 22 April 2022
    b. Product demonstration period: 23 May 2022 - 17 June 2022
        i. Week 1: 23 May 2022 - 27 May 2022
        ii. Week 2: 6 June 2022 - 10 June 2022
        iii. Week 3: 13 June 2022 - 17 June 2022

7. **Project Decision Points and Deliverables:**
    a. Proving Ground Operations Plan: 21 March 2022
    b. Proving Ground Final Report: 30 August 2022

8. **Responsibilities and Coordination:**
    a. Kevin Thiel, OU/CIWRO and NOAA/SPC - Co-Principal Investigator for Satellite Proving Ground activities taking place in the HWT in 2022
    b. Kristin Calhoun, NOAA/NSSL - Co-Principal Investigator for Satellite Proving Ground activities taking place in the HWT in 2022
    c. Kodi Berry, OU/CIWRO – EWP Coordinator

9. **Budget and Resource Estimate:** Funded through the GOES-R and JPSS Science Offices.

Product Name: Geostationary Lightning Mapper (GLM)
Primary Investigator: Kristin Calhoun (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.

Products:

- GLM Flash Extent Density (1 min, 5 min) – an accumulation of the number of flashes that pass through a given location.
- GLM Minimum Flash Area (1 min, 5 min) – the minimum 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.
- GLM Flash Points (1 min, 5 min) - parallax-corrected flash centroid locations. Mouseover provides metadata for each flash, including flash size and duration.

Concept for Operational Demonstration:

- GLM L2 data is delivered to the HWT via the SBN. Gridded products are received via LDM to the HWT cloud platform in collaboration with the Aviation Weather Center. The gridded data are displayed in AWIPS-II.

Concept for Operations:

- GLM gridded data have been distributed nationwide via LDM since 2019. The choice of additional products will be a function of HWT Feedback.

Product Name: NOAA Unique Combined Atmospheric Processing System (NUCAPS)
Primary Investigator: Rebekah Esmaili (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 multiple satellite sounders has in the past proven to be useful.

Product Overview:

- NUCAPS profiles are available over the CONUS from NOAA-20 and Aqua satellite platforms in the early afternoon. This will give forecasters two sequential overpasses to depict rapid evolution of the atmosphere. MetOp-B/-C are available in the late evening/morning over CONUS.
- 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 (IR+MW failed and MW-only passed) , and red (IR+MW and MW-only failed).
- NUCAPS retrievals with automated boundary layer modification: this year the algorithm uses the GOES Land Surface Temperature product instead of a simple surface skin temperature calculation.

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 Products:

- Vertical temperature and moisture profiles with/without GOES/RTMA modification
- Gridded temperature, moisture, stability indices, and other derived fields.

Concept for Operational Demonstration:

- Baseline NUCAPS (NOAA-20) are distributed via SBN to AWIPS. Gridded NUCAPS became operational after AWIPS version 19.2.1-29 utilizing the same data stream.
- Experimental NUCAPS from MetOp-B/-C and Aqua will be distributed via NASA/SPoRT LDM to AWIPS for display in baseline AWIPS plug-in (sounding and gridded).
- Modified NUCAPS (NOAA-20) are from the Univ. of Wisconsin DB/CSPP and distributed by CIRA's LDM.
- New software and web-based tools will be demonstrated to support non-AWIPS users. SHARPpy will provide real-time NSHARP display outside of AWIPS and access to NOAA-20, MetOp-B/-C, and Aqua from DB via NASA SPoRT. SHARPpy will be installed on the workstations to access the data.

Product Name: Optical Flow Winds
Primary Investigator: Bob Rabin (NOAA/NSSL and UW CIMSS)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Provide high resolution wind observations (2–5 km) every 5-minutes for situational awareness.
- It will be useful to assess the value of this product as a complement to the operational DMV wind product, radar and lightning data in monitoring prestorm situations, storm intensification and decay.

Product Overview:

- An experimental product is being developed using 1-minute imagery from GOES-16/17 ABI imagery to provide high resolution wind estimates at 2-4 km resolution using an optical flow technique. Due to the high resolution, these winds may be useful in monitoring divergence and local wind max/min couplets near overshooting tops to infer updraft intensity in thunderstorms and divergence and rotation in vicinity of developing tropical storms. In addition, the higher density winds may provide additional information on vertical shear between different cloud layers. The product typically provides a higher density of winds than are currently available in the operational Derived Motion Vector (DMV) satellite wind product, especially over deep convective cloud tops where cloud top temperature is relatively spatially uniform.

Product Methodology:

- Frequency: ~ 5 minutes
- Latency: ~ 3 minutes
- Input: IR (band 13) imagery at 1-minute intervals with a special enhancement to highlight small cloud top temperature variations.
- Coverage: Mesoscale sectors 1 and 2 from GOES-16 and 17

Products:

- Winds within predefined pressure layers can be selectively displayed in a unique color for that layer by clicking on the boxes below the animation controls. Since the displays would be too cluttered if the full set of winds were plotted, only a subset of wind flags at approximately 10 km intervals are displayed.
- Clicking on the “All” box displays a color enhanced image of wind speed at every grid point irrespective of the pressure level of the wind estimate.
- The “DIV” box (last on the right) displays estimated divergence from winds in the 50-200 mb layer. It assumes that there is no vertical shear across the 50-200 mb layer.
- State boundaries and surface obs are displayed with the 1000-800 mb wind overlay.
- CWA boundaries are displayed with the 800-600 mb wind overlay.

Concept for Operational Demonstration:

- The optical flow winds are currently available in real-time via a web-based display.

Product Name: Polar Hyperspectral Soundings with Microwave and ABI data (PHSnMWnABI)
Primary Investigator: Bill Smith (UW), Qi Zhang (HU), Scott Lindstrom (UW)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Model simulations give more accurate representations of atmospheric thermodynamics and dynamics (because of better initializations of 3-dimensional moisture and wind velocity) and therefore better estimates of where severe convection will develop.
- Evaluation of model output will provide important feedback to product developers on most useful products; forecasters will have exposure to a new tool to help focus attention geographically as convection develops.

Product Overview:

- This is numerical model (WRF) output that results from the assimilation of polar soundings (both infrared and microwave) that are combined/blended with ABI data to enhance their spatial and temporal resolution. The resultant distribution of moisture and motion are an accurate representation of the true atmospheric humidity and wind velocity whose evolution, predicted through NWP model satellite data assimilation, can therefore be expected to yield more accurate estimates of where severe convection will occur.

Product Methodology:

- When a Polar Overpass is colocated (in time) with an ABI scan, relationships between information from the infrared and microwave sounders on the Polar Orbiter and the imager data from the ABI on the GOES are established. Forecast model initialization is obtained through continuous, hourly interval, assimilation of high space and time resolution moisture profiles projected onto the new ABI imagery space and time distributions.

Products:

- Model estimates of updraft velocities and Significant Tornado Potential.
- Model estimates of Stability Parameters (such as MUCAPE and CAPE).
- Soundings used to initialize the model provide a useful nowcast tool before the model results are available.

Concept for Operational Demonstration:

- Gridded model output (and point source sounding input) will be delivered via LDM feed from CIMSS to HWT. Fields are also viewable outside of AWIPS here: https://www.ssec.wisc.edu/hufusion/plot-viewer/

Concept for Operations:

- Any WFO can request this product via the LDM feed.

Product Name: NOAA/CIMSS ProbSevere v3 (ProbSevere) with associated hazard models (probSevere, ProbHail, ProbWind, and ProbTor)
Primary Investigator: Mike Pavolonis (NESDIS)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Assists 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 [0-60 min].
- Algorithms incorporate multiple datasets from satellite, radar, total lightning, and NWP into easy-to-interpret products, helping to distill data during busy weather situations.
- ProbSevere guidance is CONUS-wide and day/night independent.
- Time series AWIPS-II tool
    - Double-clicking a ProbSevere object displays a window of time series of ProbSevere products.

Product Methodology:

- Spatial and temporal features are extracted and computed from satellite and radar storm objects.
- Trained gradient-boosted decision trees (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, Rapid Refresh (RAP)-derived, and Storm Prediction Center (SPC) mesoanalysis data.

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-hazards-in-one display, providing guidance on any of the above hazards.
- Products are displayed as contours around storms on radar, colored by their probability of the given hazard(s).
- Data readout is available by sampling the probability contour. This provides the exact probabilities of hazards and the detailed predictor values.
- Forecasters can display each model separately in AWIPS-II.
- Each product updates every 2 minutes.

Concept for Operational Demonstration:

- GeoJSON files will be delivered to the HWT via the LDM and converted on-the-fly in AWIPSII.

Concept for Operations:

- The ProbSevere system (v2.0) became operational at NCEP Central Operations on 14 October 2020. The primary users are radar/warning operators and mesoscale analysts in NWS WFOs. ProbSevere v3 and the time series tool may be incorporated into operations, pending forecaster evaluation.

Product Name: NOAA/CIMSS ProbSevere LightningCast
Primary Investigator: Mike Pavolonis (NESDIS)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- LightningCast assists forecasters with probabilistic guidance of convective/lightning initiation, sustainment, and cessation.
- LightningCast can be a decision support tool that directly enables users to take action, such as seeking shelter in advance of lightning onset.
- Products will be evaluated on their ability to increase forecaster confidence and situational awareness of lightning initiation, sustainment, and cessation.

Product Overview:

- LightningCast is an AI model that uses images of GOES-R ABI data to predict the probability that GLM will observe lightning (in-cloud or cloud-to-ground) in the 60 minutes following an ABI scan.
- LightningCast uses the 0.64-µm (CH02) and 1.6-µm (CH05) reflectances, and the 10.3-µm (CH13) and 12.3-µm (CH15) brightness temperatures from ABI as predictors.
- The guidance from LightningCast is day/night independent.
- The spatial resolution is reduced from 2 km to approximately 8 km to reduce noise in output.

Product Methodology:

- At one scan time, radiance data is extracted from ABI L1b files and converted into reflectances or brightness temperatures.
- These data are predictors of the trained AI model, a convolutional neural network.
- The LightningCast model predicts a probability of lightning in the next 60 minutes (as observed by GLM) for every pixel in the scan domain.

LightningCast Products:

- LightningCast generates products for 6 ABI scan domains:
    - GOES-East CONUS and both Mesoscale domains
    - GOES-West CONUS and both Mesoscale domains
- Each domain will have 2 products: a parallax-corrected probability of lightning and an uncorrected probability of lightning, resulting in a total of 12 products.
- LightningCast's latency for the CONUS domain is 25-30 seconds and for the Mesoscale domain is 3 seconds.

Concept for Operational Demonstration:

- NetCDF data will be delivered to the HWT via the LDM for each domain/product.
    - A total of 12 files per timestamp, or about 89 MB.
- The data will be viewed by forecasters in AWIPS-II with the gridded product resource. Concept for Operations:
- LightningCast may be selected for a transition-to-operations within NESDIS, pending forecaster evaluation and feedback.