GOES-R and JPSS Proving Ground Demonstration Proposal:
Hazardous Weather Testbed – 2023 Spring Experiment

1. **Project Title**: 2023 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 2023:**
    a. NOAA Unique Combined Atmospheric Processing System (Gridded NUCAPS and NUCAPS-Forecast products)
    b. OCTANE Motions & Speed Sandwich
    c. Polar Hyperspectral Soundings with Microwave and ABI data (PHS) Model
    d. NOAA/CIMSS ProbSevere LightningCast
    e. NOAA/CIMSS ProbSevere v3, with associated hazard models (probSevere, ProbHail, ProbWind, and ProbTor)

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 2023 Spring Experiment. Satellite Proving Ground activities during the Spring Experiment will take place during the weeks of May 22-26, June 5-9, and June 12-16 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 a real-time AWIPS-II (on-site and cloud-based) framework. 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 2023 Spring Experiment, live GOES-16/18 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 2023 Spring Experiment in the HWT/EWP will be as follows.

Approximately 23 participants will be involved in the 2023 Satellite Proving Ground, with 7 forecasters attending one week of on-site demonstrations and 8 forecasters per week attending two weeks of virtual demonstrations. 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. Additionally, more detailed summaries, applications, and caveats for each product will be provided to the forecasters in small groups with sufficient time for discussion and questions.

Each day will begin at 1 pm CDT and end at 6 pm CDT for the two virtual demonstration weeks. The first day of the on-site demonstration week will begin at 11 am CDT and end at 7 pm CDT. The start times for Tuesday through Thursday will happen between 10 am CDT and 1 pm CDT, and end eight hours later. The variable start time will be decided the day before, and depend on when the primary convective activity is expected to start. In both demonstration formats, Tuesday through Thursday will begin with an open discussion from the previous day's events.

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. 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 and DSS messaging 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. 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 and DSS messaging, and 6) graphical forecasts.

Monday through Thursday, live operations will end 30 minutes prior to the scheduled end time for the day, and the participants will complete their daily

surveys. Each Friday will begin with the distribution of a weekly survey, followed by a weekly debrief session to summarize the week's activities, feedback, and recommendations. For the on-site demonstration week, operations will end earlier on Thursday such that participants can develop presentations sharing their experiences in the Spring Experiment. The slides will be presented virtually Friday as part of a "Tales from the Testbed" webinar, in which scientists and NWS entities outside of Norman are encouraged to participate. Figures 1 and 2 (below) provide a visual representation of the schedule described.

On-Site Demonstration Schedule

Hour (From start)	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30	6:00	6:30	7:00	7:30
Monday	Orientation				Product Training				Operations							Daily Survey
Tuesday	Discussion/ Forecast		Operations													Daily Survey
Wednesday	Discussion/ Forecast		Operations													Daily Survey
Thursday	Discussion/ Forecast		Operations											Webinar Prep		Daily Survey
Friday	Weekly Survey		Weekly Debrief			Webinar										

Figure 1: The on-site demonstration schedule (22-26 May) in Norman, OK.

Virtrual Demonstartion Schedule

Time (CDT)	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30
Monday	Orientation			Product Training/Operations						Daily Survey
Tuesday	Discussion/ Forecast		Operations							Daily Survey
Wednesday	Discussion/ Forecast		Operations							Daily Survey
Thursday	Discussion/ Forecast		Operations							Daily Survey
Friday	Weekly Survey		Weekly Debrief							

Figure 2: The virtual demonstration schedule (5-9, 12-16 June).

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. NOAA Unique Combined Atmospheric Processing System (Gridded NUCAPS and NUCAPS-Forecast products) (Emily Berndt – STC)
        ii. OCTANE Motions & Speed Sandwich **(**Jason Apke – CIRA/CSU)
        iii. Polar Hyperspectral Soundings with Microwave and ABI data (PHS) Model (Bill Smith – UW, Qi Zhang – HU , Scott Lindstrom – UW, Anthony DiNorscia – SSAI)
        iv. ProbSevere Hazards Model (Mike Pavolonis – NESDIS)
        v. ProbSevere LightningCast (Mike Pavolonis – NESDIS)
    b. **Consumers:**
        i. Hazardous Weather Testbed

6. **Project Schedule/Duration**:
    a. Training sent to participants: 1 May 2023
    b. Product demonstration period: 22 May 2023 - 16 June 2023
        i. Week 1: 22 May 2023 - 26 May 2023 (On-site)
        ii. Week 2: 5 June 2023 - 9 June 2023 (Virtual)
        iii. Week 3: 12 June 2023 - 16 June 2023 (Virtual)

7. **Project Decision Points and Deliverables:**
    a. Proving Ground Operations Plan: 20 March 2023
    b. Proving Ground Final Report: 1 September 2023

8. **Responsibilities and Coordination:**
    a. Kevin Thiel, OU/CIWRO and NOAA/SPC - Principal Investigator for Satellite Proving Ground activities taking place in the HWT in 2023
    b. Kodi Berry, OU/CIWRO – EWP Coordinator

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

Product Name: NOAA Unique Combined Atmospheric Processing System (Gridded NUCAPS and NUCAPS-Forecast products)
Primary Investigator: Emily Berndt (NASA SPoRT/MSFC)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- NUCAPS plan view products (e.g., Gridded NUCAPS and NUCAPS-Forecast) assist forecasters with environmental analysis for anticipating convective development.
- As a situational awareness tool, NUCAPS products provide model-independent observations to supplement the observational network, SPC mesoscale analysis, and model forecasts.
- Products will be evaluated on their ability to increase forecaster confidence in convective potential and anticipated convective mode, especially in clear to partly-cloudy conditions before convection develops.

Product Overview:

- NUCAPS profiles are available over the CONUS from the NOAA-20 satellite in the early afternoon.
- NUCAPS temperature and moisture fields as well as derived parameters such as lapse rates, TPW, and stability indices can be viewed at specific pressure levels/layers.
- While Gridded NUCAPS is available valid at the time of the NOAA-20 overpass, NUCAPS-Forecast leverages a trajectory model to advance observations forward in time, expanding available observations to 6 hours out in time.

Product Methodology:

- The NUCAPS algorithm 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.
- Gridded NUCAPS is processed within AWIPS through a python-based EDEX plugin to create gridded plan view temperature and moisture fields
- NUCAPS-Forecast is passed through the HYSPLIT trajectory model to advance observations forward in time using GFS winds. The data are gridded and interest fields are calculated through the SHARPpy software.

Products:

- Gridded temperature, moisture, and derived values (lapse rates, TPW, stability indices)
- Domain over the CONUS
- Latency of approximately 40-60 minutes from the time of the overpass

Concept for Operational Demonstration:

- NOAA-20 delivered through the SBN to AWIPS are leveraged for Gridded NUCAPS. Gridded NUCAPS became operational after AWIPS version 19.2.1-29 utilizing this data stream. If HWT isn't able to leverage the NOAA-20 SBN data, these can be provided by SPoRT via LDM.
- NUCAPS-Forecast are processed at SPoRT and grib2 files for ingest and display in AWIPS will be delivered via the LDM
- Complimentary analysis with SPC Mesoscale Analysis (MU CAPE/CIN, LCL, PWAT/TPW, 700-500 mb Lapse Rates, 850 mb T/Td/Theta-e) and the PHS Model will be encouraged.
- The data will be viewed by forecasters in AWIPS with web-based visualizations available as a backup.

Product Name: OCTANE Motions & Speed Sandwich
Primary Investigator: Jason Apke (CIRA/CSU)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Provides relevant wind profile and imagery motion details inferred from cloud-drifts within each mesoscale-sector image
- Can highlight storms developing in strong wind shear and cloud-top divergence from mature convection and imbedded updrafts
- Products will be assessed in their capability to complement to the operational DMV wind product, cloud-top height, radar and lightning data in monitoring pre-storm environments, storm development, intensification, and decay

Product Overview:

- The Optical flow Code for Tracking, Atmospheric motion vector, and Nowcasting Experiments (OCTANE) Speed Sandwich is an Hue-Saturation-Value (HSV) imagery product which combines retrieved cloud drift speeds computed from a variational optical flow algorithm (color shading, color bar; m/s) tuned by comparison to ground-truth wind speed datasets with the textures (brightness) from the 0.64 μm (10.3 μm) imagery during the day (night; Solar Zenith Angle > 80°).
- Provided with each GOES-16 and -18 mesoscale sector, with ~0.5 km (~2 km) spatial resolution during the day (night)

Product Methodology:

- Computes motions by tracking brightness features (e.g., minima/maxima/gradients) in 0.64 μm (10.3 μm) satellite imagery sequences during the day (night)
- Frequency: 1-min/30-sec (same as GOES-R mesoscale sectors)
- Latency: ~3 to 5-min
- Input: Two sequential 0.64 μm and 10.3 μm images, separated by 1-min (or 30-sec depending on mesoscale sector overlaps)

Products:

- CIRA SLIDER Web Page: Speed Sandwich HSV imagery along with a companion wind barbs product (barbs colored by 10.3 μm brightness temperature)
- AWIPS: Derived motions (speed/direction) provided for each mesoscale sector

Concept for Operational Demonstration:

- AWIPS-ready NETCDF data will be delivered to HWT via the LDM for each product (16 MB/ File, ~64 MB / min)
- Imagery delivery via CIRA-SLIDER system expected, includes extensive capabilities for overlaying relevant mapping parameters and other CIRA imagery products.

Product Name: Polar Hyperspectral Soundings with Microwave and ABI data (PHS) Model
Primary Investigators: Scott Lindstrom, Bill Smith Sr., Qi Zhang, Anthony DiNorscia

Hazardous Weather Testbed, Experimental Warning Program Relevance: Provides forecasters with situational awareness for convection via short-term instability parameter forecasts useful for nowcasting when combined with GOES-R ABI Imagery, GLM, and Radar data. PHS also provides longer-term f (i.e., 4-12 hour) forecasts of STP for future convective initiation.

Product Overview: The forecast parameters are obtained from HRRR WRF model output. The model is initialized by assimilating atmospheric temperature and humidity soundings that are derived by fusing soundings obtained from direct readout polar infrared and microwave sounding radiance data during the previous seven hours to real-time 30-minute interval GOES ABI imagery data. The vertical soundings to be fused are derived from full spectrum radiance differences between the polar satellite infrared (i.e., CrIS and IASI) and microwave (i.e., ATMS and AMSU) observed spectral radiances and the radiances produced for the CrIS/IASI and ATMS/AMSU spectral channels, by a radiative transfer calculation that uses as input RAP model 2-hour forecast vertical profiles for the same time and location of the polar satellite radiance measurements. Thus, the assimilated PHSnMWnABI soundings represent the best adjustment of the RAP model 2-hr forecast model profiles needed to satisfy the satellite observed spectral radiances. Hourly interval 2-km (*i.e*., ABI) spatial resolution combined polar and geostationary satellite radiance data derived soundings are then used as input to 3-km resolution HRRR-WRF forecasts, producing the same forecast parameters and products produced by the operational HRRR model.

Product Methodology: Each forecast starts with a satellite water vapor profile assimilation cycle that uses the latest RAP model analysis (which analysis contains the influence of all operational surface and upper air observations assimilated to produce that analysis) as the background. Only the PHSnMWnABI fusion water vapor profiles are assimilated to drive maximum sensitivity of the resulting water vapor analyses to the high-resolution satellite moisture observations. The high-resolution, satellite water vapor profile data are continuously assimilated over a 3-hour period so that the HRRR-WRF model dynamics (i.e., horizontal and vertical velocity field) can adjust so as to be consistent with the time and spatial variations in the hourly 2-km resolution satellite water vapor profile measurements being assimilated. At the end of the three-hour satellite data assimilation period, the resulting analysis is used as the initial condition for the 3-km resolution HRRR-WRF model forecast cycle, from which hourly interval 3-km resolution forecast model output is produced for lead-times ranging from 0-hr (i.e., the initial analysis) to 12-hours.

Products: Half-hourly interval Atmospheric temperature and moisture profile retrievals, hourly interval forecasts of temperature, humidity, wind velocity, CAPE parameters, STP, and other forecast parameters provided by the NOAA operational HRRR model, mesoscale analyses, forecast radar reflectivity.

Concept for Operational Demonstration:
PHSnMWnABI model output can be displayed in AWIPS-II. Profile retrieval parameters (e.g., temperature and humidity profiles, cloud height, and surface-skin temperature) will be available via a satellite profile retrieval product website.

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 20 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 60 MB (9 MB compressed).
- The data will be viewed by forecasters in AWIPSII with the gridded product resource.
- Concept for Operations:
- LightningCast may be selected for a transition-to-operations within NESDIS, pending forecaster evaluation and feedback.

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:

- Machine-learning 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 AWIPSII 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 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 High-Resolution Rapid Refresh (HRRR)-derived 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 AWIPSII.
- 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.