GOES-R and JPSS Proving Ground Demonstration Proposal:
Hazardous Weather Testbed – 2025 Spring Experiment

1. **Project Title**: 2025 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 2025:**
   a. GREMLIN (GOES Radar Estimation via Machine Learning to Inform NWP)
   b. OCTANE Suite (Speed, Direction, Cloud-Top Cooling and Divergence)
   c. 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 2025 Spring Experiment. Satellite Proving Ground activities during the Spring Experiment will take place during the weeks of May 5-9, May 19-23, and June 2-6 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 cloud-based AWIPS-II 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 2025 Spring Experiment, live GOES-18/-19 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 2025 Spring Experiment in the HWT/EWP will be as follows.

Approximately 16 participants will be involved in the 2025 Satellite Proving Ground, with 5 to 6 forecasters per week attending three 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 day of the testbed will start at 1 pm CDT and end at 6 pm CDT. Monday 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. Tuesday through Thursday will begin with an open discussion from the previous day's events, followed by a brief discussion of the day's anticipated convective threat (location/timing/mode/hazards). Forecasters will then 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. 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, and 5) submitted warnings and DSS messaging.

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. Figure 1 (below) provides a visual representation of the schedule described.

Virtual Demonstartion Schedule

Hour (CDT)	12:00	12:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30
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 1: A diagram of the virtual demonstration schedule. All times are in CDT (UTC-5).

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 Radar Estimation via Machine Learning to Inform NWP (GREMLIN) (Kyle Hilburn – CIRA/CSU)
      ii. OCTANE Suite (MesoAnywhere and Cloud-Top Divergence) **(**Jason Apke – CIRA/CSU)
      iii. ProbSevere LightningCast (Mike Pavolonis – NESDIS)
   b. **Consumers:**
      i. Hazardous Weather Testbed

6. **Project Schedule/Duration**:
   a. Training sent to participants: 28 April 2025
   b. Product demonstration period: 5 May 2025 - 6 June 2025
      i. Week 1: 5 May 2025 - 9 May 2025 (Virtual)
      ii. Week 2: 19 May 2025 - 23 May 2025 (Virtual)
      iii. Week 3: 2 June 2025 - 6 June 2025 (Virtual)

7. **Project Decision Points and Deliverables:**
   a. Proving Ground Operations Plan: 4 April 2025
   b. Proving Ground Final Report: 1 September 2025

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 2025
   b. Anthony Lyza, NOAA/NSSL - HWT Executive Officer

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

Product Name: GOES Radar Estimation via Machine Learning to Inform NWP (GREMLIN)
Primary Investigator: Kyle Hilburn (CIRA/CSU)

Hazardous Weather Testbed, Experimental Warning Program Relevance:
- GREMLIN provides synthetic radar reflectivity fields to assist forecasters in areas lacking good ground-based radar coverage.
- As a situational awareness tool, GREMLIN provides information (a) when radars are down for maintenance, (b) in sparsely populated areas with gaps between radars, (c) in areas where radar beams are so high above the ground that echoes are missed, (d) over areas of complex topography where beam blockage is an issue, and (e) offshore locations.
- GREMLIN will be evaluated on its ability to increase forecaster confidence in diagnosing convective initiation and in warning issuance where radar coverage is a limiting factor.
- Since GREMLIN responds primarily to cloud-top features, it can anticipate the development of echoes on radar by 10-20 minutes, and it is possible GREMLIN may offer additional lead time in diagnosing convective initiation.

Product Overview:
- GREMLIN uses machine learning to perform ABI+GLM data fusion to estimate radar reflectivity from GOES.
- GREMLIN uses 3.9 μm shortwave IR (C07), 6.9 μm water vapor (C09), and 10.3 μm longwave IR (C13) predictors from ABI and lightning group extent density from GLM.
- GREMLIN was originally developed for the HRRR CONUS grid, but this demonstration applies the model on the 2 km ABI grids.
- Each output pixel synthesizes information over an area of about 50 pixels or 100 km in the input fields, thus GREMLIN is most appropriate for meso-alpha scales and smaller.

Product Methodology:
- GREMLIN uses a convolutional neural network trained to transform GOES ABI radiances and GLM lightning inputs to MRMS Composite Radar Reflectivity output.
- Explainable and Interpretable AI techniques have found that GREMLIN's estimates are based on (1) presence of lightning, (2) cold brightness temperatures, (3) strong brightness temperature gradients, (4) shortwave-longwave differences to see through thin cirrus, and (5) longwave-water vapor differences to identify deep convection.
- GREMLIN provides estimates over the range 0-60 dBZ, and was tuned to balance overprediction and underprediction of radar echoes at each intensity level.
- The Version-1 GREMLIN model will be demonstrated, which was trained on warm season convection producing storm reports over the eastern two-thirds of CONUS.
- For this demonstration, a parallax correction has not been applied to GREMLIN.
- Version-1 GREMLIN is known to produce spurious echoes over very cold surfaces.

Products:
- Synthetic composite radar reflectivity. Spatial resolution is the 2 km ABI grid.
- The demonstration will focus on ABI CONUS and MESO domains with temporal refresh of 5 minutes for CONUS and 1 minute for MESO with a latency of 1 minute after the end of the sector scan.

Concept for Operational Demonstration:
- GREMLIN is processed and made available through NOAA GeoCloud.
- NetCDF data files are created for display in AWIPS.
- The build is for 23.2.1 or higher, and the plugin is the GOES-R plugin.

Product Name: OCTANE Suite (MesoAnywhere and Cloud-Top Divergence)
Primary Investigator: Jason Apke (CIRA/CSU)

Hazardous Weather Testbed, Experimental Warning Program Relevance:

- Provides imagery information for mesoscale analysis and convective intensity context inferred from cloud-drifts within each mesoscale-sector image
- Products will be assessed in ability to complement native satellite imagery for forecaster monitoring of pre-storm environments, storm intensification, and decay.

Product Overview:

- The Optical flow Code for Tracking, Atmospheric motion vector, and Nowcasting Experiments (OCTANE) Suite includes products which highlight cloud-drift motion (speed and direction) and cloud-top divergence (derived using the motion fields) blended with the textures (brightness) from the 0.64 µm (10.3 µm) imagery during the day (night; Solar Zenith Angle > 80°) using a Hue-Saturation-Value approach. OCTANE is also run on CONUS imagery to increase the temporal cadence of outputs from 5-min to 1-min.
- Wind products provided with each GOES-19 and -18 mesoscale sector, with ~0.5 km (~2 km) spatial resolution during the day (night), CONUS GOES-19 products provided for MesoAnywhere (including 0.64 µm, 1.6 µm, and 10.3 µm infrared), provided in a movable ~1500 x 1500 km sub-sector within CONUS.

Product Methodology:

- *Speed/Direction:* 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), *Cloud-top Divergence:* Retrieves the horizontal divergence using layer-aware finite differencing on the motion fields, *MesoAnywhere*: Uses derived imagery motions to interpolate brightness observed between two CONUS frames at each channel.
- Frequency: Winds: 1-min/30-sec (same as GOES-R mesoscale sectors), MesoAnywhere: 1-min, Latency: Winds: ~3 to 5-min, MesoAnywhere: ~10 min, Input: Two sequential 1-min (winds) or 5-min (MesoAnywhere) 0.64 µm and 10.3 µm images.

Products:

- AWIPS: Speed/Direction HSV sandwiches, MesoAnywhere 0.64 µm, 1.6 µm, and 10.3 µm imagery, provided with AWIPS procedures to properly read and plot datasets.

Concept for Operational Demonstration:

- AWIPS-ready NETCDFs delivered to HWT via the LDM for each product (Winds: 48 MB/ File, ~192 MB / min uncompressed, ~24 MB/file compressed), and MesoAnywhere Imagery (0.64 µm: 13 MB, 1.6 µm: 10 MB, and 10.3 µm: 10 MB/file compressed).
- CTD was evaluated last year, though we will now experiment with three different scales (full resolution, medium- and heavy-smoothing). We will also work with HWT to select cases to demonstrate MesoAnywhere in environments with and without 1-min coverage.

Product Name: NOAA/CIMSS ProbSevere LightningCast
Primary Investigator: Michael 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 ABI data (and optionally) combined with MRMS 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 (CH-05) reflectances, and the 10.3-µm (CH13) and 12.3-µm (CH15) brightness temperatures from ABI as predictors as well as composite reflectivity at -10°C from MRMS.
- Predictions are made at a 2-km spatial resolution with the output reduced to an effective resolution of 8-km to reduce noise.

Product Methodology:
- At one scan time, radiance data is extracted from ABI L1b files and converted into
- reflectances or brightness temperatures.
- At the same scan time, reflectivity at -10°C is remapped to the ABI geostationary
- projection.
- These data are predictors of the trained AI model, a convolutional neural network.
- The LightningCast model predicts probabilities of lightning in the next 60 minutes (as observed by GLM) for every pixel in the scan domain.

LightningCast Products:
- LightningCast v1 – ABI only; P(≥ 1 flash in 60 min)
- LightningCast v2 – ABI + MRMS; P(≥ 1 flash in 60 min)
- LightningCast generates products for 6 ABI scan domains:
    - GOES-East CONUS and both Mesoscale domains
        - *The ABI+MRMS product is **only** available for the GOES-East CONUS domain*
    - GOES-West CONUS and both Mesoscale domains
- Each product for each domain will have a parallax-corrected and un-corrected field.
    - Parallax correction is performed with a constant cloud-height assumption of 9 km.
- LightningCast's latency for the CONUS/PACUS domains is 20 seconds and for the Mesoscale domain is 3 seconds, relative to the ABI scan end time.

Concept for Operational Demonstration:
- The data will be viewed by forecasters in AWIPSII with the gridded product resource.
- Forecasters will also be able to view output from a web-based meteogram tool.
- Forecasters will be comparing output between LightningCast v1 and v2.