Forecasting a Continuum of Environmental Threats (FACETs)
Science and Strategic Implementation Plan (SSIP)

A Guiding Document for the Research, Development and Implementation of FACETs

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Executive Summary

On June 18-19, 2014, representatives from operational forecasting; NOAA leadership; America's Weather Industry (AWI); social, behavioral, and economic sciences (SBES); and weather community stakeholders participated in a workshop in Norman, OK to lay the groundwork for modernizing the nation's watch/warning system for high-impact weather. Directed by the National Weather Service's (NWS) Science and Technology Infusion Portfolio Manager, this "Development Team" was assembled by the National Severe Storms Laboratory (NSSL) and the Storm Prediction Center (SPC) to create this document, the Science and Strategic Implementation Plan (SSIP), as a guide in developing and implementing a holistic, next-generation hazard messaging paradigm called Forecasting a Continuum of Environmental Threats (FACETs).

An outgrowth of NOAA's Weather Ready Nation (WRN) initiatives, FACETs is designed to replace the NWS's 1960s-era deterministic (yes/no), product-centric methodologies with a modernized, science-based system delivering a continuous stream of high-resolution, probabilistic hazard information extending from days to within minutes of an event. FACETs is optimized for user-specific decision making through the integrated application of social/behavioral sciences. This document describes the steps that will need to be taken to reach the lofty goal of making FACETs a reality and dramatically improving the nation's practices for forecasting and communicating high-impact weather.

FACETs divides the high-impact weather forecasting process (or continuum) into a series of seven, inter-related components or "facets." These facets are:

1. Method & Manner: The nature of watches, warnings and advisories (WWA, e.g., deterministic, text-based information created from zone or polygon-based hazard information).
2. Obs & Guidance: The tools and data by which watch/warning decisions are achieved (e.g., radar, satellites, meteorological observations, numerical weather prediction, statistical guidance, forecaster-to-forecaster interaction, etc.).
3. The Forecaster: The knowledge, skills and abilities of forecasters needed to make effective forecast decisions.
4. Tools: The equipment used to create and disseminate hazard information.
5. Usable Output: The format, content, equipment and media by which the hazard information is communicated.
6. Effective Response: All aspects of the recipient's response (or non-response) to NWS hazard messages, including all factors leading up to the receipt of the message (e.g., education, preparedness, situational awareness, understanding, response and recovery).
7. Verification: Quantitative and qualitative measures taken to validate the scientific integrity and effectiveness of the hazard messaging program and to inform improvements in the system.

The SSIP Development Team proposes a multi-year, multi-disciplinary, "project of projects" approach to develop these seven facets into a viable, modernized operational approach to high-impact weather and water forecasting and communication. NSSL will lead research and development activities centered on probabilistic forecasting applications, guidance, models (Warn of Forecast), and techniques. It will also lead extensive testing of those items in the Hazardous Weather Testbed (HWT) and Operations Proving Ground (OPG) to reduce the risk of failure and enhance the benefits of the modernization. Social, behavioral and economic science (SBES) researchers specializing in human factors, psychology, and communication, for example, will be guide the efforts on forecaster interaction with probabilistic data, public risk awareness/response, and risk communication, respectively. Likewise, key stakeholders from media, AWI, and emergency management will be involved in all relevant aspects of FACETs development and evaluation; starting from the initial steps of projects so as to ensure effective final implementation of the concepts in their respective communities.

Several important "drivers" are behind this effort, including:

1. FACETs is a "delivery mechanism" for the output from future storm-scale, convective-resolving models such as Warn on Forecast. Without FACETs, the potential benefits of (and NOAA investment in) such technological advances will not be fully realized. NWS forecasters would continue issuing deterministic, low-resolution, text-based, hazard message products.
2. Without a modernized system like FACETs, deficiencies in the existing hazard forecasting paradigm, as identified in the WRN initiatives, will persist.
3. NOAA's 5-Year R&D Plan contains the following objectives/targets under the WRN category: "Next-generation warning concepts will be developed and tested to improve these desired societal responses through the delivery of quantitative and user-specific information."
4. The NIST report from the Joplin, MO tornado of 22 May 2011 included Recommendation 16: "…that tornado threat information be provided to emergency managers, policy officials, and the media on a spatially-resolved, real-time basis by frequently updating gridded probabilistic hazard information that is merged with other GIS information to supplement the currently deployed binary warn/no warn system." (NIST NCSTAR 3). FACETs addresses this recommendation.
5. FACETs positions NOAA to support continued growth of America's Weather Industry which is committed to partnership with the NWS.
6. The ongoing NWS hazard simplification project which is using social science to improve the public understanding and use of hazardous weather messaging.

The benefits of pursuing FACETs include (1) a fully-integrated continuum of calibrated weather threat information that will refine and improve the protective decision-making of communities, organizations, and individuals; (2) "False Alarm Areas" of warnings reduced by at least 30%; (3) copious, new opportunities for AWI to develop client-serving applications fed by NWS PHI; and (4) more useful, actionable, and recipient-specific hazardous weather information, as informed by social/behavioral sciences. Each of the aforementioned benefits will have significant and measurable cost savings for society and economic opportunity. By achieving its goal of reducing tornado warning areas by 30%, for example, the FACETs paradigm will save over $124M in lost worker productivity annually (calculations available upon request).

SSIP Implementation and Administration

Over 40 discrete projects of varied complexity and duration were identified by the Development Team to move from the current WWA paradigm to that of FACETs (see Appendix A). Most projects are focused on a particular facet or portion thereof, with specific outcomes, estimated costs, projected timetables, interdependencies and necessary steps identified. Some of the WRN-identified projects (Lindell and Brooks 2012) have been included as part of these FACETs projects. Seven phases of research, development and implementation (RD&I) are proposed for each high-impact weather type, starting with severe convective weather and flash flooding. These phases are:

- <u>Foundational research and development (Phases 1-4)</u>
  - Phase 1: Existing/Ongoing projects at the outset of the SSIP;
  - Phase 2: Critical baseline projects upon which future projects depend;
  - Phase 3: Mid-course projects not necessary at the outset;
  - Phase 4: Late-course projects necessary before operational testing;
- <u>Initial testing of FACETs concepts in operational environments (Phases 5 and 6)</u>
  - Phase 5: Operational Test and Evaluation (OT&E);
  - Phase 6: Risk Reduction conducted at multiple NWS offices (regional);
- <u>Full implementation (Phase 7)</u>
  - Phase 7: Nationwide training and implementation;

The SSIP Development Team membership will be reconstituted into a "FACETs Leadership Team" responsible for overseeing and guiding the implementation, administration and growth of the FACETs SSIP. The SSIP will be the guiding document for the Leadership Team's work.

The FACETs Executive Coordination Group (ECG), comprised of key NWS and OAR leadership, will continue serving in an oversight capacity. The ECG will give approval to the Leadership Team to move the SSIP from phase to phase. This approval will be based heavily on successful completion of Use Case (horizontal) evaluations (see below).

Given the complexity of the project and the high number of proposed projects, a three-dimensional strategy will be employed to ensure overall success. In short, FACETs will be addressed in horizontal, vertical and depth-wise fashions.

Depth-wise RD&I refers to the efforts directed toward successfully completing each of the projects identified by the Development Team. This includes the research, development and implementation of the supporting science, tools, methodologies, products, and best practices of each project.

There is a risk that projects may become disconnected and/or isolated from each other, so a horizontal approach will be employed to ensure cross-facet cohesion and compatibility of the discrete projects. Such "horizontal" evaluations will be applied through high-impact weather scenario "Use Cases" conducted in the Hazardous Weather Testbed, Operational Proving Ground and elsewhere, as appropriate. Use Cases will regularly test FACETs in an end-to-end fashion. At least three Use Cases will be conducted for each of the seven phases described above. The results of the Use Cases will be presented to the ECG and serve as key decision points (KDPs) for approval to proceed to the next phase (or retrench).

Finally, FACETs is intended to address all environmental threats (hence, the "ET" in FACETs), so expanding its concepts from severe convective and flash flooding event to other threat types (e.g., winter weather, hydrology, tropical, fire weather, etc.) will be a priority. This will constitute the vertical nature of the SSIP administration. As each facet matures, there will be new "vertical" components added to it.

Costs, Milestones and Deliverables

The costs and number of projects given in this report are <u>very rough estimates</u> based on their expected scope and timetables. In all likelihood, there will be considerable consolidation and cost-sharing between projects as their details, timing and investigators become better defined.

Total estimated costs of the entire FACETs program for severe convective weather and flash floods is on the order of $18.45M or $3.1M per year over the span of six years (FY17-FY23). 46 distinct projects have been identified in the following four general tracks (with several falling into multiple tracks):

- Physical science (16 projects, $5.4M total)
- Software development (13 projects, $4.6M)
- Social/behavioral/economic science (23 projects, $7.2M)
- Training and Outreach (3 projects, $1.3M)

The following deliverables are based on the estimates of phase completions, costs per phase and the number of projects in each of four broad categories:

- Phase 1 deliverables:
  - Use Cases 1-3 completed
  - PHI Tool transition to AWIPS-II initiated
  - Concept of operations developed
  - 7 Projects ($1.4M total)
- Phase 2 deliverables:
  - Use Cases 4-6 completed
  - Baseline studies initiated
  - PHI Tool transition to AWIPS-II completed.
  - 15 Projects ($3.7M total)
- Phase 3 deliverables:
  - Use Cases 7-9 completed
  - 30 Projects ($4.82M total)
- Phase 4 deliverables
  - Use Cases 10-12 completed
  - OT&E initiated.
  - 34 Projects ($4.01M total)
- Phase 5 deliverables
  - Use Cases 13-15 completed

    - OT&E completed.
    - 21 Projects ($1.99M total)
- Phase 6 deliverables
    - Use Cases 16-18 completed
    - Risk Reduction conducted at multiple NWS offices (regional).
    - 18 Projects ($1.58M total)
- Phase 7 deliverables:
    - Full FACETs implementation for severe convective and flash flood operations
    - Streamlined R2O mechanisms for continuous improvements to the operational FACETs paradigm, including applied SBES evaluations and research.
    - 16 Projects ($1.46M total)

Specific funding for the FACETs projects has not been identified, although several funding opportunities are being (or will be) pursued. Such "catch-as-catch-can" funding is an inefficient means of supporting a significant, long-term program like FACETs so, at a minimum, the SSIP is intended to provide sustained guidance to keep the projects active and focused. As funding opportunities are identified, they can be directed toward the project(s) chronologically according to Appendix B.

Summary

As it has been socialized throughout the research, operational, legislative, and end-user communities, the FACETs concept has received broad, strong and uniform support. At the conclusion of the NWS-funded SSIP Development Team Workshop in June 2014, the participants gave resounding and unanimous support for FACETs work to continue. It was unequivocally stated that "OAR and NWS must stand together in support of making the FACETs vision a reality." The basis for this statement was the participants' recognition that FACETs, having originated in NOAA's WRN activities, is an obvious means of achieving many of the WRN objectives.

As a framework for progress, FACETs establishes a means of connecting, coordinating and guiding existing and/or future hazardous weather forecasting R&D concepts toward a common, over-arching vision. The WRN meetings identified the need for such a vision. In its absence, well-intended watch/warning improvement projects are often undertaken in NOAA but with little or no coordination or connection between them. Likewise, the WRN meetings identified challenges within the hazardous weather forecasting system by documenting action items, white papers and recommended projects. Rather than addressing these challenges in an ad-hoc, piecemeal manner (i.e., tinkering with the existing system), FACETs is designed to address them comprehensively by reinventing the overall system. The current WRN findings, recommendations and energy – along with the trajectories of society, technology and science – strongly suggest the time is right for a modernized, scientifically-robust, and user-enabling system for communicating hazardous weather information (i.e., a reinvented watch/warning paradigm).

This SSIP is intended to deliver that system.

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Forecasting a Continuum of Environmental Threats (FACETs) Science and Strategic Implementation Plan (SSIP)

I. Introduction: The SSIP

Supported and encouraged by the National Weather Service (NWS) Science and Technology Infusion (STI) Portfolio Manager, the National Severe Storms Laboratory (NSSL) and the Storm Prediction Center (SPC) convened a workshop to initiate crafting of a Science and Strategic Implementation Plan (SSIP) for a next-generation watch/warning/advisory (WWA) concept known as Forecasting a Continuum of Environmental Threats (FACETs). Held in Norman, Oklahoma on June 18-19, 2014, the workshop established a SSIP Development Team comprised of representatives from operational forecasting; NOAA leadership; America's Weather Industry (AWI); social, behavioral, and economic sciences (SBES); and weather community stakeholders. Several other researchers and operational forecasters from in and around the National Weather Center attended the workshop, as well. The purpose of the workshop was to collect insights, suggestions and ideas to be included in the SSIP which is to then serve as a "Master Plan" for research, development and implementation (RD&I) of FACETs. This document is the culmination of that effort.

The main narrative body of this SSIP describes the FACETs vision, along with proposed means of achieving it. Appendix A will contains detailed descriptions of projects proposed to build and implement FACETs. It includes expected outcomes, costs, timetables, milestones and connections to other projects. The authors acknowledge neither the FACETs description sections of this SSIP nor the details in Appendix A are fully-comprehensive or definitive because proposed projects will certainly identify the need for additional research and development work. Additional funding will be necessary as such discoveries are made. Flexibility in scope and direction will be critical to the subsequent success of FACETs.

II. FACETs

The first official severe convective storm watches and warnings were issued by the U.S. Weather Bureau (USWB) in 1965 (NOAA 2005). Since that time, efforts to improve the USWB and then the NWS) severe convective watches and warnings have generally centered on advancing hydrometeorological science, numerical weather prediction and remote sensing technologies. Indeed, these efforts brought about significant improvements in forecaster performance and public safety (Polger et al. 1994, Golden and Adams 2000, Simmons and Sutter 2005, Stensrud et al. 2009). Advances in the communication of weather hazards were greatly aided by advances in modernized telecommunication and broadcast technologies, including the introduction of NOAA Weather Radio (NWR) dissemination in the 1960s, standardized bullet-format products in the 1990s (NOAA 2012), and storm-based, or polygon, warnings in 2007 (Jacks and Ferree 2007). Through considerable interaction with AWI, all these advances have resulted in improved hazardous weather support to society. Despite these advances in our scientific knowledge, observational capabilities, communication infrastructure, and AWI partnering; the underlying approach to delivering official NWS weather and water hazards information remains the same: Text-based, deterministic (binary) polygon-based geospatial information. Society, technology and science all clearly have evolved beyond the days of official USWB bulletins communicated via teletype. By several measures, the current approach to NWS WWA is ripe for reinvention. FACETs represents such a reinvention.

In FACETs, a nearly-continuous stream of high-resolution hazardous weather information, extending from days to within minutes of an event, is driven by cutting-edge scientific tools, and is optimized for user-specific decision making through the integrated application of SBES. The guiding principles of FACETs are that it will be modern, effective, scientifically robust, holistic, unifying, and enabling for the recipients of the information. With these ambitious goals in mind, FACETs also strives to retain the effective aspects of the existing paradigm (e.g., a "first, do no harm" philosophy). Standard, deterministic watches and warnings will still be issued in the FACETs paradigm (at least in the early phases), but they will be much more precise (smaller) and generated in an entirely different manner. The components of facets are described in the next section.

A. The Structure and Organization of FACETs

FACETs is built on the premise of a comprehensive reinvention of the entire WWA paradigm, rather than making simple incremental enhancements of the individual system components. While there is certainly merit in individual component improvement, such actions have impacts up and down the hazard messaging "chain" which may result in negative consequences in other steps of the process or have, at best, marginal, unsubstantial impacts. Doswell et al. (1999) defined the components of the hazardous weather warning process as forecast, detection, warning decision, dissemination, and public response. We offer an expanded, holistic version of this while dividing the process (or continuum) into a series of seven, inter-related components or "facets." These facets are:

1. Method & Manner: The nature of watches, warnings and advisories (e.g., deterministic, text-based information created from zone or polygon-based hazard information).
2. Obs & Guidance: The tools and data by which hazard forecast decisions are achieved (e.g., radar, satellites, meteorological observations, numerical weather prediction, statistical guidance, forecaster-to-forecaster interaction, etc.).
3. The Forecaster: The knowledge, skills and abilities of forecasters needed to make effective forecast decisions.
4. Tools: The equipment used to create and disseminate the hazard information.
5. Usable Output: The format, content, equipment and media by which the hazard information is communicated.
6. Effective Response: All aspects of the recipient's response (or non-response) to hazard information, including all factors leading up to the receipt of the message (e.g., education, preparedness, situational awareness, understanding, response and recovery).
7. Verification: Quantitative and qualitative measures taken to validate the scientific integrity and effectiveness of the hazard forecasting and communication program and to inform improvements in the system.

By design, the order of these facets matches the flow of the hazardous weather forecasting process. For example, once the hazard messaging ***methods*** have been established – which is done by the agency well before the first severe weather event takes place – ***observational and guidance data*** are collected for the ***forecaster*** to evaluate and make a decision, after which ***tools*** are used to create ***output*** and elicit a desired ***response***. Finally, ***verification*** of the system's success is conducted.

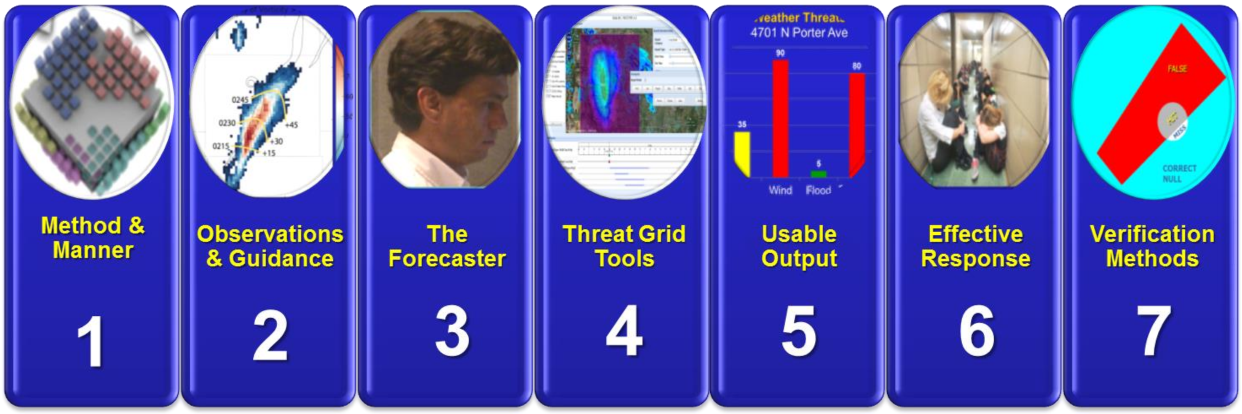

Figure 1. The facets and structure of FACETs.

B. The Facets of FACETs

<u>Facet #1: Method and Manner</u>

At the heart of the FACETs paradigm is a shift to a fundamentally different "Method & Manner." The deterministic, yes/no hazardous weather forecasting practice currently employed by the NWS is replaced by grid-based, threat probability forecasting. This is a critical point, because the grid-based threat forecasting paradigm will have significant impacts on (and opportunities for) the components "downstream." The reinvented nature of FACETs starts with and depends upon this fundamental change.

While probabilistic forecasting has been a staple of NWS forecast operations for years (e.g., probability of precipitation), it has never been applied universally to severe weather forecasting at the local level. The NWS Storm Prediction Center has been issuing specific phenomenon probabilities in its outlooks and, as such, has blazed the trail for probabilistic severe weather messaging. Taking the probabilistic information to the warning scale, in which the probabilities of some forecast phenomenon or event occurring at grid points, presents a whole new level of complexity. Such probabilities can relate to the occurrence of a specific hydrometeorological phenomenon (e.g., one-inch hail, a tornado, snow or rain accumulation of a particular amount, etc.) or more complex information such as the probability of a phenomenon's arrival or onset time. **It is imperative that, throughout all continua of time, space, phenomena, impacts and forecasters; probabilities applied in the FACETs paradigm must remain well-calibrated.** In other words, a forecast probability of one-inch hail occurrence within ten miles of a point must be uniformly understood, consistently applied and statistically reliable.

In an operational sense, it is unrealistic for forecasters to create these probability grids from scratch, given the unlimited number of probabilities possible for all hydrometeorological phenomena. With FACETs, it is envisioned that first-guess probability data will be derived from model output or statistical analyses to aid the forecaster. Probability grids initialized in this way can be compared to standard observation and guidance information (e.g., radar, mesoanalyses, numerical weather prediction, real-time statistics, etc.) and adjusted by forecasters using sophisticated, science-based, grid-manipulation tools (see below).

While there are several additional components to FACETs, the application of probabilistic hazard grids are at the heart of the paradigm. It is postulated that data mining of such grids through innovative display tools and straightforward conveyance of threat probabilities, can provide enhanced and continuous communication of threat information in a manner that will generate all existing warning content and far exceed the limitations of deterministic, text-based products.

The probabilistic hazard grids approach does not preclude the issuance of legacy (zone/polygon and text-based) watches and warnings. In fact, legacy products are envisioned to be issued for the foreseeable future, but automatically extracted from the grids based on pre-determined threshold values. This approach is expected to result in smaller areas for legacy severe convective warnings because the emphasis would be on a single phenomenon (e.g., hail) as opposed to covering multiple phenomena with a tornado warning polygon as is the practice today.

By continuously updating hazard probability grids, forecasters are expected to rely less on their own deterministic “warn/don’t warn” decisions and more on delivering nuanced threat information decision makers need. (In fact, early testing of the FACETs concept in the Hazardous Weather Testbed have indicated this is the case.) By providing gradients of threat via hazard probability grids, sophisticated end users can set their own thresholds for action based on their specific needs (e.g., hospitals, nursing homes, large venue facilities, etc.). Hazard probability forecasting also affords the development of new products addressing high impact but “non-severe” weather events such as lightning and sub-severe wind. Given the significant potential for new services and products afforded by such forecasting (see Facet #5), the AWI would have tremendous opportunities for new and/or enhanced service delivery.

<u>Facet #2: Observations and Guidance</u>

This facet contains the broad array of tools and technologies used by forecasters to make severe weather forecasting decisions. As noted above, this includes remote sensing tools (e.g., radars and satellites), meteorological observations, storm spotter reports, numerical weather prediction, statistical guidance, and even forecaster-to-forecaster interaction. Owing to its breadth, diversity, and underlying purpose of informing forecasters on the present and future states of the atmosphere, this facet also receives the bulk of R&D support.

While advances in remote sensing technologies will continue to aid, inform and improve the forecaster’s operational forecast decisions; output from numerical models and statistical analyses will have the most direct application to probabilistic hazard forecasting. Storm-scale ensemble models such as Warn on Forecast (WoF), for example, are a promising frontier in severe weather forecasting. Output from these models will be probabilistic in nature, which provides an obvious opportunity for NWS forecasts to move into the realm of probabilistic hazard forecasting. It would be unfortunate for advances in storm-scale model output to go under- or un-realized because of the continued use of deterministic, text-based watch/warning products by the NWS. FACETs, therefore, provides the means by which advances in storm-scale numerical weather prediction can be turned into more refined and actionable information for end users. FACETs provides a delivery mechanism for model-generated probabilistic output. This output will aid forecasters in grid initializations – much as numerical model output is currently used to initialize routine forecast grids in the AWIPS Gridded Forecast Editor (GFE).

Other tools are envisioned which will provide statistical (probabilistic) assessments of storm-scale "behaviors" (see MYRORSS references in Appendix A). Based on radar and environmental data reanalyses, these applications are ostensibly real-time, storm-scale, model output statistics-like (MOS) guidance which can give forecasters probabilistic projections of a specific storm's longevity, intensity and attendant phenomena. Again, output from these applications can be used to populate the storm-scale probabilistic hazard grids.

Guidance also comes from forecaster-to-forecaster interaction. While such interactions may work smoothly within a NWS office, intramural coordination is complicated by geographic separation between offices. Grid consistency is a challenge for synoptic scale forecasts – and will be made even more challenging with ever-decreasing time and space scales of storm-scale hazard grids. Forecast consistency is further complicated when national offices such as the SPC do not operate on the same grids as local WFOs. It is logical, then, to consider using a single, shared database of probabilistic hazard grids to ensure forecast consistency across temporal and spatial continua. The SPC has begun exploratory work in this area, with the intent that next-generation guidance for WFO forecasters would come from gridded SPC outlooks, watches and discussions. In other words, SPC-generated probabilistic hazard *guidance* grids would flow down-scale to populate the local WFO grids.

Facet #3: The Forecaster

Being a new paradigm for NWS forecasters as it applies to severe weather operations, the use and application of probabilistic hazard grids will require considerable training for meteorologists and hydrologists. This will include advanced training on probabilistic threat information, uncertainty conveyance, use of new guidance resources, etc. The successful implementation of FACETs (and the forecasters who will make it happen) will be jeopardized without these renewed and extensive training efforts.

While this facet is devoted to "The Forecaster," the role of the forecaster will actually extend through ALL facets of the FACETs paradigm. In other words, there will be a long-standing and vital role for forecasters throughout the reinvented severe weather forecasting process. Tools are envisioned to streamline and simplify the increasingly-complicated tasks for a forecaster, but there is nothing remotely resembling full-automation of the forecast process in the FACETs paradigm. A fighter pilot analogy could be made here. As the technologies used in fighter jets became increasingly sophisticated, so did the relevance and value of a well-trained pilot. The same can be said for forecasters making increasingly complex forecast decisions, using probabilistic hazard grid generation tools, and providing enhanced decision support services.

There is a significant cultural change that the FACETs approach would bring to NWS operations, and it goes well beyond the mechanics of grid initiation and manipulation. It is likely some forecasters will have a difficult time moving from a deterministic, product-centric mode in which a final WWA issuance decision is made, to one in which such legacy products "fall out" of the forecaster-adjusted grids. There is a great deal of esteem and pride associated with being the one who makes the hazard forecast issuance decision. While that "decision" would still originate with the forecaster, the means by which it is derived will be fundamentally different. This cultural change will need to be addressed carefully.

Facet #4: Tools

This facet applies to the tools forecasters use to ingest, manipulate, update and disseminate probabilistic hazard grids in a rapid, low-effort manner. Presently, the Graphical Forecast Editor (GFE), a component of Advanced Weather Interactive Processing System (AWIPS), is used in this way to forecast sensible weather grids (e.g., wind, temperatures, sky cover, precipitation probabilities, etc.) and some hazardous weather grids for watches and non-convective warnings. In anticipation of grid-based severe weather forecasting moving down-scale, NOAA's Global Systems Division (GSD) is developing "Hazard Services" software for the AWIPS-II operational platform. NSSL and GSD researchers are collaborating on Hazard Services development with probabilistic hazard grids concepts in mind. Given the speed at which storm-scale decisions need to be made, AWIPS-II must include tools for rapid and effective grid interactions by forecasters. Sophisticated, science-based "recommenders" must be designed to facilitate this rapid decision-making and creation. Additional interactive tools are envisioned to expedite the probabilistic hazard forecasting process (e.g., a "supercell widget" which one would sweep across the model-initialized hail, wind and tornado threat grids to adjust their paths all at once). Interaction between GSD, NSSL, human factors experts, and others is imperative to ensure such capabilities exist and are well-tested, streamlined, and effective.

NSSL has been prototyping a Probabilistic Hazard Information (PHI) Tool since 2008 (Kuhlman et al. 2008), with forecaster testing taking place in the Hazardous Weather Testbed. Such tools are essential to the effective implementation of FACETs. Human factors expertise must be applied to the layout and functionality of any interface for probabilistic hazard guidance and grid generation in AWIPS II. Further testing plans of the PHI Tool are described in Appendix A.

Facet #5: Usable Output

In the spirit of "first, do no harm," it is essential that clearly articulated, risk-based hazard information (.i.e., containing uncertainty and impact information) are maintained as NWS products in the FACETs paradigm. While probabilistic hazard grids are the primary focus of the paradigm, legacy products would still initially be necessary (via extraction from grids, however), because AWI and its customers have become familiar with the WWA terms and products. NWS has engaged social scientists to explore possible alternatives to the current WWA system, and to explore approaches for graphically displaying hazard information using a combination of limited colors and symbols to highlight risk (see references to NWS Hazard Simplification Project in Appendix A). Any shift away from the existing WWA system would require extensive coordination and careful execution.

By focusing on specific, storm-based phenomena, however, watches and warnings naturally would have more specific information. Severe Thunderstorm Warnings, for example, might include probability distributions for hail sizes, wind thresholds, lightning frequency and rainfall amounts; thereby providing greater definition to the legacy polygon. As the FACETs approach (continuous flow of information) becomes more commonplace, the use of watches and warnings may become less necessary and even obsolete.

While initially retaining legacy watches/warnings – albeit in a refined manner – is a goal of FACETs, a more overarching goal is to deliver a continuous, rapidly-updated stream of probabilistic hazard information at high spatial resolutions from days to seconds prior to an event. The point is to consider FACETs as a means of delivering a continuum of weather threat information and not (only) intermittent, deterministic products. The power of FACETs is in the ability of recipients and value-adding enterprises to "mine" user-specific, actionable information from this high-resolution continuum of data. This data mining can serve a wide variety of displays, formats, and applications (see Section 5 in Appendix A). Several examples are envisioned, most founded on the principle that – all things being equal – people are interested in their own welfare and safety first. Operational forecasting experience suggests they want to know answers to these five basic questions:

1. Will it (the "event") affect me?
2. When will it start?
3. How bad will it get?
4. When will it end?
5. What should I do?

This facet encompasses the delivery of probabilistic hazard information in a wide variety of formats, displays, and media that must address these "Big 5 Questions" in some manner. With the aid of SBES insights, data-mining from probabilistic hazard grids can yield exciting, innovative ways to do this and protect people more effectively during hazardous weather.

Facet #6: Effective Response

Any progress made in the previous five facets would be for naught if the end user response is ineffective or wrong. This facet focuses on effective and appropriate end-user response. This is an area of considerable discussion in the meteorological community, especially with regard to gaining agreement as to what "effective and appropriate" end-user response might be. Is it appropriate, for example, to leave a home during a tornado warning and flee in a vehicle? Most would suggest it is not, but with ample lead time (and improved forecasting skill), the answer to that question may change. There are wide-ranging questions regarding "effective and appropriate response" that must be addressed in a research framework. This is where SBES integration would have the greatest impact, although contributions of these disciplines are essential in all facets of the threat forecasting process.

The Big 5 Questions described above are also part of this facet. They are entwined in the stages of risk perception and response described by Mileti and Sorenson (1990): Reception, understanding, belief, confirmation and personalization of a warning message. Assuming the warning has been received in the first place, the Big 5 Questions are all part of the process to understand, believe, confirm and personalize the warning message. Meteorologists are usually prepared to answer the first four questions, but must give stock answers for the fifth – only because personal situations are not known and liability concerns arise. Secondary questions usually follow, as well (e.g., "Will my house survive?"), but the "Big 5 Questions" are foremost in the minds of those impacted by weather hazards. The better forecasts and decision support services can answer these five questions in a timely and reliable fashion, the greater confidence people will have in the supplied information and, presumably, the better their response will be. This last assumption is not a given, as described in the section on Facet #6.

What matters most is how the individual responds to the "stimuli" of the weather enterprise. Forecasters have been heard to say, "They should just do what I say," as if that were sufficient impetus for proper response to watches and warnings. Sadly, such idealism has limited success in the real world. Instead, Dr. Jeff Lazo (personal communication) points out, "We must learn how people respond to weather information and threats, accept that reality, and then build the system to work within that reality and to achieve the desired outcomes." Put another way, the term "publics" is used in the SBES community to acknowledge the wide variety of public vulnerability, awareness, responsiveness and resilience to extreme weather. FACETs, and its underlying research, must account for all aspects of the publics. Although FACETs intends to engage SBES in all aspects of its paradigm, it is at this juncture of physical science and human response that the application of SBES is most needed.

A vital component of the FACETs paradigm will be the routine, rigorous measurement of public response to NWS present and future severe weather forecasting paradigms. This will begin with a baseline measurement (see Appendix A, Project 6.A.1) that will be repeated annually to gauge the effectiveness of changes brought about by FACETs. It will also be helpful in informing new initiatives and policies ***before*** they are implemented.

Facet #7: Verification

FACETs (and probabilistic hazard grids, specifically) will greatly enhance NOAA's ability to measure the effectiveness of severe weather hazard forecasting and response. It begins with the notion that the forecasts and observations are applied to the same coordinate system - a geospatial grid. In the existing verification system, a single observed phenomenon verifies a warning - no matter how large or ill-positioned the warning polygon might be. Likewise, a forecasted low-probability, high-impact phenomenon that does not occur is considered a false alarm, resulting in a penalty for the forecaster and his/her office. By mapping the occurrence (or non-occurrence) of a phenomenon to a probabilistic grid, more meaningful analyses can be derived (e.g., Brier scores, false alarm duration, false alarm area, site-specific lead time, site-specific end time, etc.). These improved verification methods would provide more useful insight into forecaster training needs and the overall threat forecasting process. This would require a change in verification methods to include high-resolution, ground-truth information (where possible) and/or proxies that yield information about the certainty of an event when exact "ground truth" does not exist.

This facet goes beyond verification of hydrometeorological forecasting skill scores. Another component of this facet will be the verification of effective response by hazard information recipients. This would be an entirely new aspect in NWS verification and one which is typically reserved for Service Assessments after major weather events. Such measures and data-collection techniques would need to be devised through collaboration with SBS, emergency management and AWI partners. The aim would be to have post-event measures of response become standard operating procedure for NWS offices. A key challenge among many, however, would be to ensure the data-collection techniques have minimum impact on workload. Appendix A describes several of these new approaches.

C. FACETs Drivers & Benefits

There are several driving forces behind FACETs. Chief among them has been the WRN initiative and associated meetings in Norman, OK (2011) and Birmingham, AL (2012). The purpose of these meetings was to identify issues and challenges with the existing hazard forecasting paradigm. FACETs was designed to address several of these challenges will integrate SBES research – a major need expressed by the WRN activities – into its development work, while addressing decision support needs through grid-based probabilistic forecasts.

Other bases for this proposed work include:

1. NOAA's 5-Year R&D Plan contains the following objectives/targets under the WRN category: "Next-generation warning concepts will be developed and tested to improve these desired societal responses through the delivery of quantitative and user-specific information."
2. The NIST report from the Joplin, MO tornado of 22 May 2011 included Recommendation 16: "…that tornado threat information be provided to emergency managers, policy officials, and the media on a spatially-resolved, real-time basis by frequently updating gridded probabilistic hazard information that is merged with other GIS information to supplement the currently deployed binary warn/no warn system." (NIST NCSTAR 3).
3. NSSL Warn on Forecast research is maturing to the point where there is a recognized need for an effective "delivery mechanism" for probabilistic output. FACETs is designed to serve that purpose.
4. OAR has funded a FACETs-related investigative project through the Special Early-Stage Experimental or Development (SEED) Project Initiative. The $394K funding for two years and is narrowly-focused on ingesting & "managing" storm-scale probabilistic data from multiple sources.
5. OAR funding through the (SEED) Project Initiative has already yielded early prototypes of a system by which grid-based, probabilistic, storm-scale data from a variety of sources can be effectively managed, manipulated and displayed. Although quite early in the developmental stage, the results are promising. This has set the stage for testbed experimentation of probabilistic warning concepts.

6. The FACETs concept has been socialized widely throughout the NWS and OAR; with initial presentations given to private and public sector stakeholders. Response to the watch/warning system concepts offered through FACETs has been universally positive and receptive – with the understanding that considerable R&D is still needed.
7. Robust growth of consumer electronics, including and especially mobile devices – allowing the rapid delivery of weather warnings with innovative displays, which can be used to further enhance a user's understanding of a hazard in order to inspire them to take required actions.
8. Continued growth of America's Weather Industry and the weather media which is committed to partnership with the NWS within Weather-Ready Nation and other programs in order to deliver weather warnings accurately and quickly to end users in a variety of products and services, substantially increasing the reach and value of NWS weather warnings when compared to dissemination methods previously used.

The benefits of pursuing FACETs include (1) a fully-integrated continuum of calibrated weather threat information that will refine and improve the protective decision-making of communities, organizations, and individuals; (2) "False Alarm Areas" of warnings reduced by at least 30%; (3) copious, new opportunities for the private sector to develop client-serving applications fed by NWS PHI; and (4) more useful, actionable, and recipient-specific hazardous weather information, as informed by social/behavioral sciences.

Each of the aforementioned benefits will have significant and measurable cost savings for society and economic opportunity for AWI. By achieving its goal of reducing tornado warning areas by 30%, for example the FACETs paradigm will save over $124M in lost worker productivity annually (calculations available upon request).

III. Putting the SSIP into Action

As expressed by the SSIP Development Team during its June 2014 workshop, modernizing the nation's WWA system will require considerable planning, coordination, leadership, and support – but it is imperative and timely for the changes to occur. This section describes how the Development Team proposes taking the FACETs SSIP from static document to a fully-modernized program.

A. The Phases of SSIP RD&I

Over 40 discrete projects of varied complexity and duration were identified by the Development Team to move from the current WWA paradigm to that of FACETs (see Appendix A). Most projects are focused on a particular facet or portion thereof, with specific outcomes, estimated costs, projected timetables, interdependencies and necessary steps identified. Some of the WRN-identified projects (Lindell and Brooks 2012) have been included as part of these FACETs projects. To place some order and flow to these projects, Appendix B lists them quasi-chronologically in the following phases:

- Foundational research and development (Phases 1-4)
    - Phase 1: Existing/Ongoing projects at the outset of the SSIP.
    - Phase 2: Critical baseline projects upon which future projects depend.
    - Phase 3: Mid-course projects not necessary at the outset.
    - Phase 4: Late-course projects necessary before operational testing.
- Initial testing of FACETs concepts in operational environments (Phases 5 and 6)
    - Phase 5: Operational Test and Evaluation (OT&E), including training development, and testing at the Operational Proving Ground and a few select WFOs;
    - Phase 6: Risk Reduction conducted at multiple NWS offices (regional);
- Full implementation (Phase 7)
    - Phase 7: Nationwide training and implementation, including the establishment of streamlined R2O mechanisms for continuous improvements to the operational FACETs paradigm and applied SBES research.

B. Leadership, Governance and Administration

Upon completion of this document, this SSIP Development Team membership will be reconstituted into a "FACETs Leadership Team" responsible for overseeing and guiding the implementation, administration and growth of the FACETs SSIP. The SSIP will be the guiding document for the Leadership Team's work.

The FACETs Executive Coordination Group (ECG), comprised of key NWS and OAR leadership, will continue serving in an oversight capacity. The ECG will give approval to the Leadership Team to move the SSIP from phase to phase. This approval, will be based heavily on successful completion of Use Case (horizontal) evaluations (see below).

NSSL will be the lead organization in the day-to-day RD&I of FACETs, although with considerable collaboration throughout NOAA and the weather community at large. The Severe Weather and Warning Applications Technology (SWWAT) Team of NSSL's Warning Research and Development Division will be the primary entity leading and/or conducting the work.

Semi-annual progress reports will be provided to the ECG by the FACETs Leadership Team for consideration of necessary course corrections and SSIP modifications. These reports will be managed and created by the NSSL FACETs Program Leader.

C. The Three-Dimensional Approach to SSIP Administration

Given the complexity of FACETs and the high number of proposed projects, a careful, methodical and holistic strategy must be employed to ensure success. This will consist of a three-dimensional strategy by which aspects of FACETs will be addressed horizontally, vertically and depth-wise, as described below.

1. Depth-wise RD&I

Depth-wise RD&I refers to the efforts directed at successfully completing each of the projects listed in Appendix A. This includes the research, development and implementation of the supporting science, tools, methodologies, products, and best practices of each project. Given the variety, complexity, scope and funding of the projects, they will each naturally progress at different rates. The progress of each project will be monitored by the FACETs Leadership Team and tracked according to Technical Readiness Levels (TRLs) in NAO 216-105.

2. Horizontal Evaluation and KDPs

Because the depth-wise approach necessarily will focus on development of individual FACETs projects, there is a risk that the projects may become disconnected and/or isolated from each other. To prevent this and ensure cross-facet cohesion and compatibility of the discrete projects, "horizontal" evaluations will be applied through high-impact weather scenario "Use Cases" conducted in the Hazardous Weather Testbed, Operational Proving Ground and elsewhere, as appropriate. These Use Cases will regularly test FACETs in an end-to-end fashion, starting with the simplest of cases (i.e., "baby steps") to more complex cases as the capabilities of FACETs mature. While some facets might have little in the way of depth-wise work completed in early phases, some aspect of each facet will be tested regardless. Figure 2 depicts this approach.

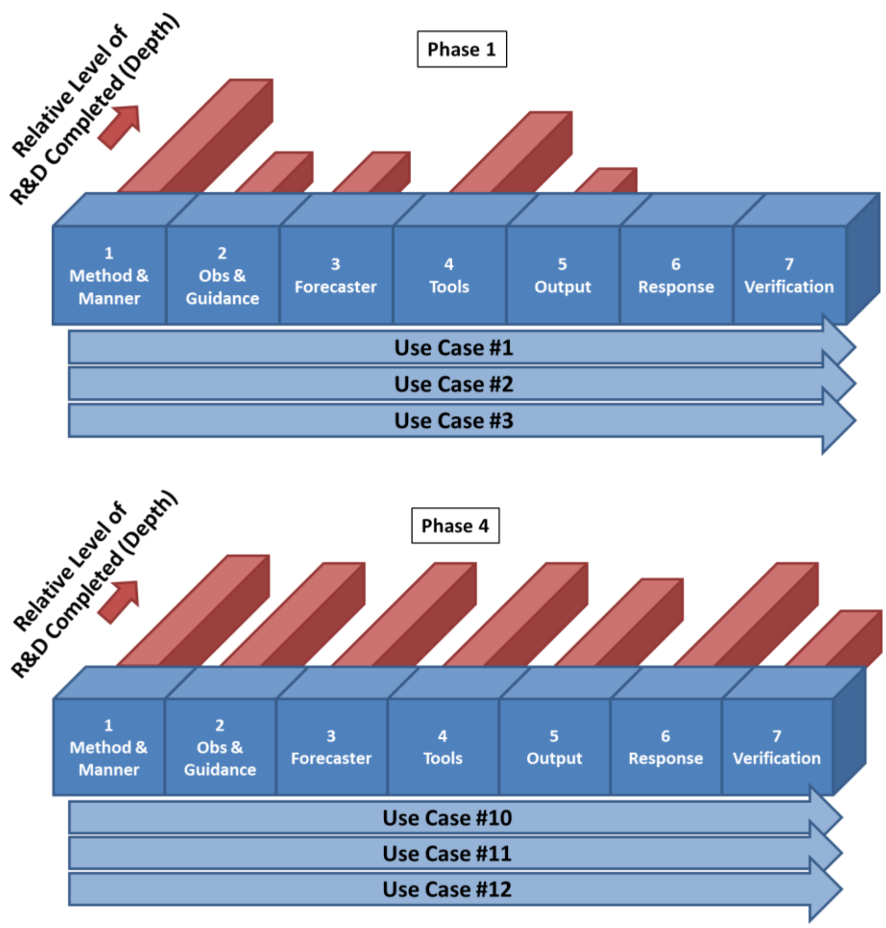

Figure 2. Schematic of the horizontal (end-to-end) application of Use Cases for two sample phases. The depth of the inward-directed (red) bar indicates the relative level of R&D completed in that particular facet, in that particular phase.

At least three end-to-end Use Cases will be conducted for each of the seven phases described above. The results of the Use Cases will be presented to the ECG and serve as key decision points (KDPs) for approval to proceed to the next phase (or retrench).

The successful implementation of FACETs will depend on the entire Weather Enterprise being well-coordinated and integrated into the project. Horizontal evaluation will give stakeholders and system owners from research through service deliver the opportunity to provide valuable feedback, validation, and risk reduction. Regular meetings with Weather Enterprise constituents, leaders, stakeholders and FACETs developers will be held to further monitor progress, revise goals and share results.

3. Vertical Growth

Initially, FACETs work will focus on convection-related, short-fused phenomena. By design, FACETs is intended to address all environmental threats (hence, the "ET" in FACETs), so expanding probabilistic hazard information concepts to other threat types (e.g., winter weather, hydrology, tropical, fire weather, etc.) will be a priority. This will constitute the vertical nature of the SSIP administration. As each facet matures, there will be new "vertical" components added to it (see Figure 3). This will be accomplished in a staggered fashion. In other words, as

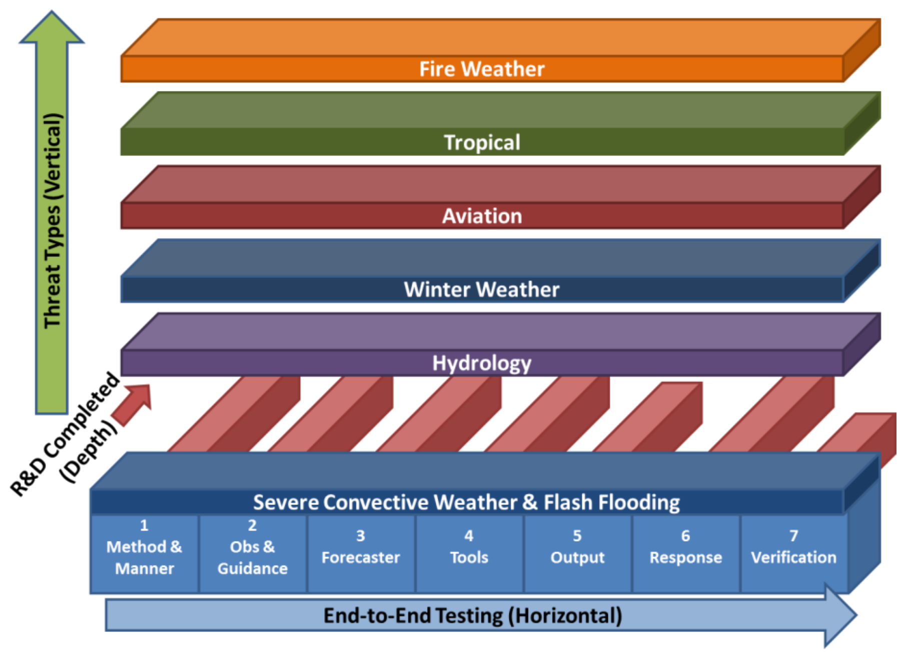

Figure 3. Similar to Figure 2, but with the vertical dimension added for different threat types. As FACETs matures, the horizontal and depth-wise efforts will be directed to different threat types (vertical).

the severe convective/flash flooding layer of FACETs reaches its later phases, other layers (e.g., hydrology and winter weather) will begin in Phase 1 and step forward methodically (see Figure 4). The detailed projects contained within these layers are beyond the scope of this SSIP, but the method of RD&I for each layer is modeled herein.

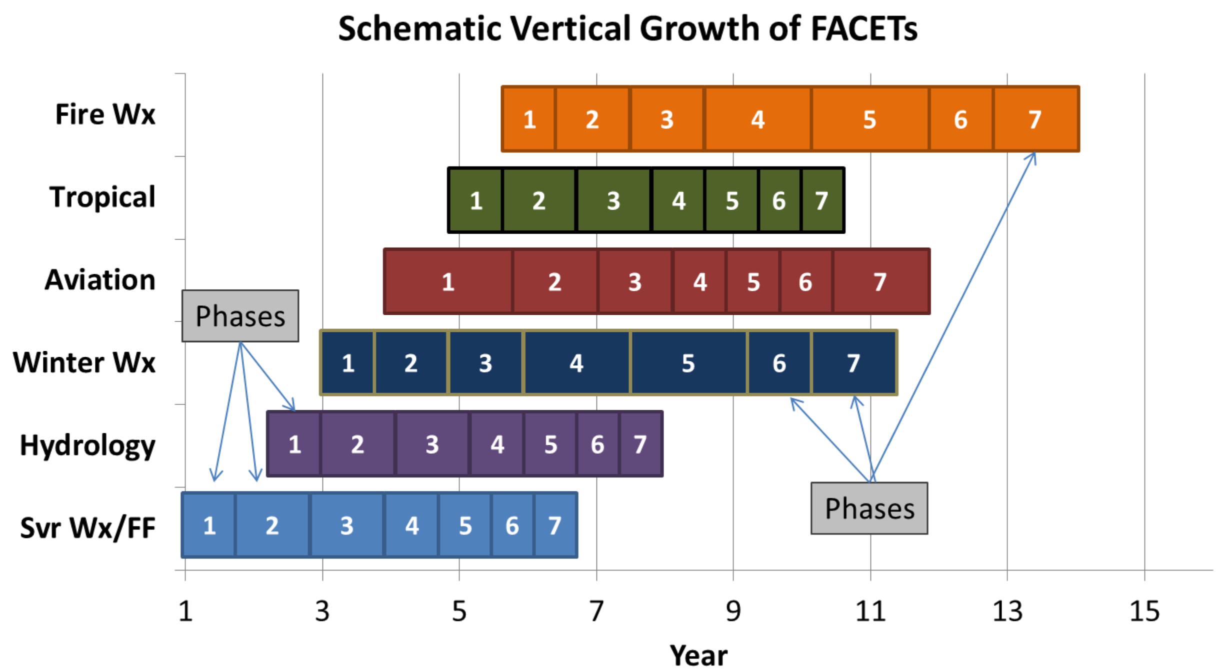

Figure 4. A conceptualization of the phase-by-phase timeline for FACETs' vertical growth into other threat types.

IV. Costs, Milestones and Deliverables

The costs and number of projects given in this report are very rough estimates based on their expected scope and timetables. In all likelihood, there will be considerable consolidation and cost-sharing between projects as their details, timing and investigators become better defined.

Total estimated costs of the entire FACETs program for severe convective weather and flash floods is on the order of $18.45M or $3.1M per year over the span of six years (FY17-FY23). 46 distinct projects have been identified in the following four general tracks (with several falling into multiple tracks):

- Physical science (16 projects, $5.4M total)
- Software development (13 projects, $4.6M)
- Social/behavioral/economic science (23 projects, $7.2M)
- Training and Outreach (3 projects, $1.3M)

The following deliverables are based on the estimates of phase completions, costs per phase and the number of projects in each of four broad categories:

- Phase 1 deliverables:
  - Use Cases 1-3 completed
  - PHI Tool transition to AWIPS-II initiated
  - Concept of operations developed
  - 7 Projects ($1.4M total)
    - 4 Physical Science projects ($800K total)

        - 1 Software project ($200K total)
        - 3 Social/behavioral/economic science projects ($450K total)
- Phase 2 deliverables:
    - Use Cases 4-6 completed
    - Baseline studies initiated
    - PHI Tool transition to AWIPS-II completed.
    - 15 Projects ($3.7M total)
        - 6 Physical Science projects ($1,500K total)
        - 3 Software projects ($750K total)
        - 6 Social/behavioral/economic science projects ($1,400K total)
- Phase 3 deliverables:
    - Use Cases 7-9 completed
    - 30 Projects ($4.82M total)
        - 10 Physical Science projects ($1,773K total)
        - 8 Software projects ($1,093K total)
        - 11 Social/behavioral/economic science projects ($1,755K total)
        - 1 Training and outreach project ($50K total)
- Phase 4 deliverables
    - Use Cases 10-12 completed
    - OT&E initiated.
    - 34 Projects ($4.01M total)
        - 9 Physical Science projects ($1,014K total)
        - 12 Software projects ($1,522K total)
        - 14 Social/behavioral/economic science projects ($1,322K total)
- Phase 5 deliverables
    - Use Cases 13-15 completed
    - OT&E completed.
    - 21 Projects ($1.99M total)
        - 2 Physical Science projects ($102K total)
        - 7 Software projects ($509K total)
        - 11 Social/behavioral/economic science projects ($872K total)
        - 2 Training and outreach projects ($400K total)
- Phase 6 deliverables
    - Use Cases 16-18 completed
    - Risk Reduction conducted at multiple NWS offices (regional).
    - 18 Projects ($1.58M total)
        - 2 Physical Science projects ($102K total)
        - 5 Software projects ($259K total)
        - 10 Social/behavioral/economic science projects ($772K total)
        - 2 Training and outreach projects ($400K total)
- Phase 7 deliverables:
    - Full FACETs implementation for severe convective and flash flood operations
    - Streamlined R2O mechanisms for continuous improvements to the operational FACETs paradigm, including applied SBES evaluations and research.
    - 16 Projects ($1.46M total)
        - 2 Physical Science projects ($102K total)

- 5 Software projects ($259K total)
- 8 Social/behavioral/economic science projects ($647K total)
- 2 Training and outreach projects ($400K total)

Specific funding for the FACETs projects has not been identified, although several funding opportunities are being (or will be) pursued. This includes a FY17 Program Change Summary (PCS) request NSSL has made to OAR to explicitly support this work for several years. Additional funding opportunities may include requests for proposals (RFPs) announced by OAR's Office of Weather and Air Quality (OWAQ) for HWT experiments, NWS's R2O program, and the NSSL Director's Discretionary Research Fund (DDRF). Such "catch-as-catch-can" funding is an inefficient means of supporting a significant, long-term program like FACETs, so the SSIP is intended to provide sustained guidance to keep the projects active and focused. As funding opportunities are identified, they can be directed toward the project(s) chronologically according to Appendix B.

V. Summary

FACETs is a next-generation concept for NWS hazardous weather forecasting and communication that relies on the creation and effective dissemination of risk-based, probabilistic hazard information. Considerable planning, support, research, development and collaboration is necessary to affect this "heavy lift" of science, operations and societal change. This FACETs Science and Strategic Implementation Plan is to serve as the "Master Plan" for affecting that change. Over 40 projects have been identified herein, along with a cautious and careful administration strategy for ensuring effective implementation of the entire FACETs concept.

Acknowledgements

Several members of the social, behavioral, economic and physical sciences community have contributed to this document. The Development Team is grateful to the contributions of Dr. Christopher Karstens (OU/CIMMS), Dr. Laura Myers (Social Science Research Center, Mississippi State Univ.), Dr. Joseph Ripberger (OU Center for Applied Societal Response) and Mr. Charles Kuster (OU).

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APPENDIX A

The Proposed Projects of FACETs

Facet #1 (Method and Manner) Areas of Emphasis

At the heart of the FACETs paradigm is a shift to a fundamentally different "Method & Manner." The reinvented nature of FACETs starts with and depends upon this fundamental change to Probabilistic Hazard Information (PHI) forecasting at warning scales in which the probabilities of some forecast phenomenon or event occurring are assigned to grid points. It is postulated that PHI, through data mining, innovative display tools and straightforward conveyance of threat probabilities, can provide enhanced and continuous communication of threat information in a manner that will generate all existing warning content and far exceed the limitations of deterministic, text-based products. The projects described in this section (facet) are focused on changing of the method and manner of watches/warnings and advisories.

1.A. Overarching concepts

Project 1.A.1. "Probability of What?"

Outcome(s):

- Defined and calibrated event probabilities (via meteorological science) throughout all temporal and spatial scales and for all phenomena.
- Define impacts probabilities (via SBES).

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
1 - Top	2	100	200	1	All

Project Details: Define and determine the probabilities to be use for each high-impact categories. Ensure the guidance and forecasts are "calibrated," meaning whatever the source of data used (e.g., radar, convective resolving models, ensembles, etc.), the threat probabilities mean the same to the forecaster as it does to the end user - even as data sources and models evolve.

Some specific tasks required in this project include:

1. Define and determine "impactful distances" for each weather phenomenon (e.g., 10 miles for tornadoes?)
2. Define and determine relevant and forecastable threshold categories (probability distributions) for:
    a. Tornado intensity;
    b. Hail size;
    c. Downburst wind speed;
    d. Flash flood guidance exceedance;
    e. Lightning first strike;
    f. Snowfall amounts.
3. Define and determine relevant and forecastable threshold categories (probability distributions) for icing amounts, lightning flux excess, temperature extremes, fire weather.

Project 1.A.2. The External Name

Outcome(s): Marketable "external-facing" name for FACETs concept.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
4 - Low	1	50	50	3	

Project Details: FACETs, an acceptable acronym for the meteorological profession, is not easily-understandable to those outside the weather enterprise. A more self-descriptive and marketable name is needed as the frontispiece of FACETs.

Some specific tasks required in this project include:

1. Work with marketing experts and focus groups to establish a self-descriptive name/brand for the FACETs concept.
2. Market the concept using a comprehensive education strategy.

Facet #2 (Observations and Guidance) Areas of Emphasis

This facet contains the broad array of tools and technologies used by forecasters to make watch/warning decisions. This includes remote sensing tools (e.g., radars and satellites), meteorological observations, storm spotter reports, numerical weather prediction, statistical guidance, and even forecaster-to-forecaster interaction. Output from numerical models and statistical analyses will have the most direct application to PHI forecasting – and vice versa. Storm-scale ensemble models such as Warn on Forecast (WoF), for example, are a promising frontier in severe weather forecasting. Output from these models will be probabilistic in nature and this provides an opportunity for NWS forecasts to move into the realm of PHI. This facet describes projects that will promulgate that movement.

2.A. PHI-Enabling Analysis

Project 2.A.1. Multi-Year Reanalysis of Remotely Sensed Storms (MYRORSS)

Outcome(s): Initial probabilities for different threats based on environment, storm mode and radar attributes from data mining of MYRORSS radar climatology.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	4	300	1200	1 2 3 4	7

Project Details: This project (and related projects in this section) will address several of the objectives put forth in Weather Ready Nation "Project A" by Lindell and Brooks (2012) which cites: "For the large spatial and time frame studies, consideration of long records of observed environmental conditions and storm intensity will be carried out using well-established statistical techniques. The ongoing creation at the Storm Prediction Center of the necessary database of the environmental conditions associated with thousands of tornadoes should make this relatively easy to accomplish. ...observations would be assimilated into high-resolution numerical models in order to fill in the four-dimensional structure of the storm and estimate the importance of various physical quantities and processes in the development, maintenance, and dissipation of tornadoes, as well as their intensity."

Some specific tasks required in this project include:

1. Created blended radar data sets w/ 1km or better horizontal / vertical grid spacing with 5 minute temporal resolution over CONUS from 1996 - 2014 (and on).
2. Identify storm clusters at multiple scales (individual convective cells, up through large convective systems).
3. Identify properties of these clusters (both environmental and radar characteristics).
4. Track clusters - generate trends of storm properties for entire storm lifetype for each cluster.
5. Data mining - generate probability (P) of [tornado/wind/hail/heavy precip/lightning/mesocyclone/etc] for each storm cluster. P(event is ongoing) and P(event will occur in X minutes) within the cluster.
6. Creation and data mining of dual-polarization WSR-88D data (2012 and later).
7. Creation and data mining of NWP-based model assimilation fields at 1 km resolution or better.
8. Incorporate satellite, lightning, and MADIS surface observations into MYRORSS data set.

Issues/Questions:

1. Will grid-based verification (FACET 7) development be sufficient to provide a baseline against which to quantify training and validation data sets?

Project 2.A.2. Incorporate Satellite data into MYRORRS, and MYRORSS data into GOES-R Convective Initiation "Probability of Severe Weather" application

Outcome(s): PHI informed by satellite as well as radar-based probabilities.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	3	100	300	2 3 4	2.A.1

Project Details: Cintineo et al. (2014; U. of Wisconsin) tested a blended satellite/radar technique in the HWT during Spring 2014 that uses the WDSS-II/MRMS feature identification and tracking techniques to predict the probability of severe weather for these blended features. Additionally, GOES-R will provide new convection initiation detection capabilities as well as storm life cycle information when it becomes operational later in the decade.

Some specific tasks required in this project include:

1. Add satellite data (existing GOES) to MYRORSS data mining and determine enhancements to probabilistic nowcast skill.
2. Enhance the MYRORSS data base with GOES-R products, such as total lightning from the Global Lightning Mapper.

Issues/Questions:

1. Is it possible to leverage ongoing and future GOES-R funded research to enable a better blended data solution than is currently available?

Project 2.A.3. Improved dual-polarization MRMS algorithms

Outcome(s): Improved hydrometeor classification/sizing and severe storm feature detection.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	4	150	600	2 3 4	7

Project Details: Many new applications are under development at different agencies that take advantage of dual polarization radar moments. This project examines which of these can be leveraged for use in FACETs as well as which new techniques should be developed.

Some specific tasks required in this project include:

1. Catalog existing dual-polarization radar algorithms for severe storm feature detection and hydrometeor size/classification.
2. Develop single-radar and MRMS applications to detect tornado debris signatures and severe convective wind hazards, and to categorize hail size. Quantify the errors in these estimations.
3. Investigate data assimilation techniques to improve detection capabilities.

Issues/Questions:

1. Is it possible to leverage work being done at NSSL and the ROC on single-radar WSR-88D algorithms and MRMS algorithms to inform this project?
2. Is it possible to leverage Warn-on-Forecast dual-polarization results?
3. Point validation data sets need to be very robust (SHAVE, mPING, new methods).

2.B. PHI-enabling guidance 0-2 hours

Project 2.B.1. Relate probabilities from MYRORSS and other sources to existing warning framework

Outcome(s): Detailed comparison of statistically-based threat strike probabilities and mesoscale guidance for forecaster education/analysis and to establish baseline performance metrics.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	3	200	600	2	2.A.1, 3.C, 7

Project Details: This project establishes the skill of the existing watch/warning paradigm on the scale of PHI spatial (~ 1 km) and temporal (~ 1 min) output resolution.

Some specific tasks required in this project include:

1. Comparison of historical warning and watch products to probabilities on a consistent grid, calculating lead time and other skill measures at each grid point for inputs such as:
    a. MYRORSS base probabilities;
    b. GOES-R Cintineo et al. Severe Weather Probability guidance;
    c. SPC probabilistic guidance (especially pre-initiation);
    d. HRRR/HRRRe-scale NWP;
    e. Integration of FLASH guidance for flash flood hazard characterization.
2. Coordinate with all developers (modellers at all scales, MYRORRS, etc.) to establish local through national scales for consistency of probabilities.
3. Ongoing development of training materials / forecaster education.

Project 2.B.2. Automated PHI guidance and legacy watch/warning comparison

Outcome(s): Real-time automated PHI guidance and legacy watch / warning monitoring capability for research, operations, and training.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	2	50	100	3 4	2.A.1, 2.B.1, 3.C, 7

Project Details: This project establishes real-time capability for automated PHI guidance using the MRMS system as the initial input and building on that capability as other guidance matures.

Some specific tasks required in this project include:

1. Setup real-time comparison web site for these experimental probabilistic guidance fields with operational watches/warnings on local-through-national scales for consistency of probabilities.
2. Maintenance / monitoring / analysis of real-time monitoring web site.
3. Incorporate experimental storm-scale and mesoscale model forecasts (WoF, etc.)
4. Transitional experiment in which forecasters attach probabilistic hazard information to current polygon warnings, coupled with robust verification.
    a. This will begin forecaster calibration.
    b. This, combined with MYRORSS, could be exploited to guide PHI first guesses for the envisioned continuous probabilistic "warning" phase.

Issues/Questions:

1. Latency issues for model products.
2. Requires robust verification techniques at fine spatial / temporal scales.

Project 2.B.3. Incorporation of FLASH concepts into FACETs

Outcome(s): FLASH guidance information fully functional as PHI data, and best practices identified from HWT experiments.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	3	150	450	3 4	

Project Details: FLASH is a probabilistic guidance tool (among other things) for flash flood forecasting which has been developed by NSSL researchers. This project will support the integration of these data and techniques into the FACETs/PHI Tool concept.

Some specific tasks required in this project include:

1. Integration of FLASH guidance for flash flood hazard characterization as PHI.
2. Test and evaluate the benefit and utility of FLASH guidance in the FACETs environment.

Project 2.B.4. Warn-on-Forecast Integration

Outcome(s): Storm-scale ensemble guidance incorporated into PHI guidance.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	3	100	300	2 3 4	

Project Details: The goal of the the Warn-on-Forecast project is to produce reliable storm-scale ensemble output for 0-2 hour forecast of severe convective weather. Ongoing research suggests that a combination of extrapolative and statistical techniques (from the MYRORSS database) and storm-scale NWP may provide an improved forecast than either of the techniques alone.

Issues/Questions:

1. Must work closely with Warn-on-Forecast project to leverage results and implement science.

2.C. PHI-enabling guidance > 2 hours

Project 2.C.1. Severe weather / environment relational database

Outcome(s): Statistical database of storm events by type in various environments for WSR-88D era (1996-present) for use in operational mesoscale situational awareness and mesoscale/stormscale model improvements.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	5	150	750	3	2.A.1

Project Details: The project leverages ongoing research at SPC and NSSL/CIMMS to development a database of storm mode and severity for various background environments. This unique data set can be used to validate numerical weather prediction forecasts at the storm scale.

Some specific tasks required in this project include:

1. MYRORSS-based climatology of severe weather events:
   a. diurnal / seasonal / annual
   b. filtered by background environment (RAP/HRRR/SPC OA)
   c. matched with SPC storm type and tornado climatology research (Smith et al. 2012)
2. Development of a technique to match storm-scale objects in convection allowing NWP models with MYRORSS radar-based objects.
3. Annual updates of climatological information in out-years.

Issues/Questions:
1. Draws on existing SPC research, may require access to SPC meteorologists for collaboration.

2.D. Local-national integration

Project 2.D.1. SPC Transitional PHI

Outcome(s): Phased implementation of hourly probabilistic (tornado, hail, wind) severe weather outlooks to provide robust PHI background for PHI warning operations.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	2	75	150	3	

Project Details: The project develops hourly-updated probabilistic background grids (PHI) to bridge the current single day outlooks to continuous probabilities on the watch timescale, including localized threat channels and evolution within current traditional watches. It provides support for multi-hour DSS at local and national scales.

Some specific tasks required in this project include:

1. Test and evaluate SPC outlooks based on a synthesis of CAM NWP guidance, observations, MYRRORS (as applicable) and forecaster insight.
2. Develop and test hourly updated, hourly PHI grids to bridge the current single day outlooks to continuous probabilities on the watch timescale, including localized threat channels and evolution within current traditional watches.
3. Develop and test continuously evolving "watches" with local lead times driven by decision needs and SBES.

Issues/Questions:

1. Communication challenges for continuously evolving, multi-hour PHI would be a risk reduction for all communities (NWS, decision makers, AWI) prior to more challenging minute-by-minute warning scale PHI.

Facet #3 (The Forecaster) Areas of Emphasis

There will be a long-standing and vital role for forecasters throughout ALL facets of the FACETs paradigm. Tools must be developed to streamline and simplify the increasingly-complicated tasks for a forecaster and forecasters must learn to use them. Beyond the mechanics of PHI grid tool manipulation, the FACETs/PHI approach will bring a considerable cultural shift to NWS operations (i.e., in cross-CWA interactions, basic communication of probabilistic information, etc.). The projects described in this facet address these issues.

3.A. Forecaster education in a PHI setting

Project 3.A.1. Storm characteristics and behaviors in legacy NWS warnings and watches

Outcome(s): Information about baseline forecaster skill and calibration.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	2	100	200	2	2.A, 2.B, 7

Project Details: The project establishes a baseline of forecaster skill in determining the severity of storms inside and outside of legacy warnings and watches. The inputs to this experiment include the MYRORSS data set (2D data fields, environmental data, storm clusters), NWS warning polygons, SPC watch boxes, and MADIS surface observations. Attempt to ascertain if a given warning was reactionary or proactive, or if storms may have produced unreported severe weather (whether under a warning at the time or not). Attempt to quantify how changes in technological inputs into the warning decision making process (e.g. super-resolution WSR-88D, SAILS, dual-pol, lightning, satellite upgrades, etc.) have affected forecaster performance.

Some specific tasks required in this project include:

1. Determine the radar/environmental characteristics of storms when watches/warnings were issued (structure, motion, CAPE/shear, etc).
2. Track what happened in each case (Maintain severity? Decay/intensify? Something else surprising?)
3. Determine characteristics of unwarned storms (and storms warned after become severe).
4. Take verification issues into account:
    a. population density / road network;
    b. time of day;
    c. forecaster effort / gaming of verification system (e.g. spatially large warnings with one storm report to verify);
    d. Run in real-time, can determine probability that a warning will verify given meteorological input data fields and GIS information.

3.B. Define and ensure infusion of human expertise

Project 3.B.1. Continuous evaluation of PHI with and without human input

Outcome(s): Determination of where the human adds skill to the forecast - which tasks can be partially or fully automated to distribute forecaster workload.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	2	150	300	3 4	2.B.2, 3.A, 4

Project Details: Automated guidance, statistical databases of storm behavior, and storm-scale NWP will inform the first-guess PHI fields. Forecasters interact with these guidance sources and other to create PHI output fields. The project measures how forecaster changes to inputs affect skill and reliability of PHI output fields in a HWT setting using real-time and simulated real-time scenarios to answer the questions:

1. Where does the forecaster add skill to the probabilistic forecast and which tasks can be partially or fully automated to reduce forecast workload?
2. How does real-time verification feedback affect forecaster skill?
3. How do forecasters use recommender information and real-time verification information? Does how they use it change over the course of a one-week intensive HWT experiment (or over a longer period if the same forecasters revisit the HWT at a later time)?
4. Should forecasters manipulate the PHI guidance probabilities (that is, create the probabilities themselves), or should they manipulate the input data fields used to create the PHI guidance (such as correcting erroneous radar data and letting the statistical PHI model regenerate new probabilities with the corrected input)? How does this affect consistency between forecasters or different forecast offices?

3.C. Forecaster understands and conveys uncertainty through PHI

Project 3.C.1. Document and understand the current forecaster warning decision-making process

Outcome(s): An analysis of forecaster probabilities used in the warning decision process.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
1 - Top	3	150	450	2	4, 5

Project Details: Forecasters make warning decisions for a variety of reasons, but no assessment has ever been made on the actual probabilistic values used in that warning decision. This project will establish a baseline of forecaster decision-making thresholds which will assist in determining if future applications are adding value to the process. This project is related to WRN "Project C" (Forecasters' Construction of Warning Polygons), as described in Lindell and Brooks (2012). Although focused on polygon construction, the underlying research questions still apply. To wit, "...this research could provide the basis for conducting periodic "recalibration" of experienced forecasters. Such a procedure could be used to identify a forecaster's "drift" away from an agency-wide consensus standard and seek to identify the reasons why it occurred. In some cases, this judgmental drift might be nothing more than random error but, in other cases, it might provide evidence of important lessons learned from the forecaster's experience." And… "Once a set of standardized measures of polygons has been defined, it will be possible to compute derived measures of personal consistency and interpersonal agreement. In turn, these derived measures can be analyzed to determine if there are systematic differences in personal consistency and interpersonal agreement by, for example, level of experience or region of the country.

Some specific tasks required in this project include:

1. Conduct HWT experiments to determine forecaster probabilistic thresholds for warning decisions.
2. Determine how WDTB training they received (if any) compares to actual practice.
    a. Time since training? Keeping current on skills?
    b. Need to understand their calibration to the current warning system
3. Conduct NWS-wide survey asking forecasters to provide a probabilistic prediction of an event occurring given different scenarios (environment, radar signatures, etc.)

Issues/Questions:

NWS-wide survey could possibly be conducted by WDTB.

Project 3.C.2. Extensive forecaster training

Outcome(s): Every forecaster trained on the methodologies and best practices of the FACETs paradigm.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
1 - Top	3	300	900	5 6 7	All

Project Details: This is the training program for NWS forecasters on how the FACETs paradigm will work operationally. WDTB will take the lead on this effort and supported by transitional funding. It will occur in Stage 2, but the underlying concepts and practices need to be identified earlier.

Some specific tasks required in this project include:

1. HWT testing to determine best practices.
2. Work through AMS to ensure university curricula are updated to match evolving needs of NWS and weather industry.
3. Promote PHI tool before it comes. Education must come before. Trust will be lost otherwise.
4. Develop and deliver training on PHI concepts.
5. Develop and train on definitions of probabilities in time and space.
6. Training for any stakeholder feedback exercises in developing CONOPS from baseline studies, including any HWT exercises

Issues/Questions:

1. Dependent on having the base probabilities develop, and the overall concept formed such that it doesn't change too much from the original course (or major confusion may result).

Facet #4 (Tools) Areas of Emphasis

This facet applies to the tools forecasters use to ingest, manipulate, update and disseminate PHI in a rapid, low-effort manner. Presently, the Graphical Forecast Editor (GFE), a component of AWIPS, is used in this way for routine forecasting of sensible weather grids (e.g., wind, temperatures, sky cover, precipitation probabilities, etc.) and some hazardous weather grids for watches and non-convective warnings. In anticipation of grid-based forecasting moving down-scale, NOAA's Global Systems Division (GSD) is developing "Hazard Services" software for the NWS AWIPS-II operational platform. NSSL and GSD researchers are collaborating on Hazard Services development with PHI concepts in mind. Given the speed at which storm-scale decisions need to be made, AWIPS-II must include tools for rapid and effective grid interactions by forecasters. Sophisticated, science-based "recommenders" are being designed to facilitate this rapid PHI decision-making and creation by forecasters. Additional interactive tools are envisioned to expedite the PHI generation process (e.g., a "supercell widget" which one would sweep across the model-initialized hail, wind and tornado threat grids to adjust their paths all at once). Interaction is underway between GSD, NSSL, human factors experts, and others to ensure such capabilities exist and are well-tested, streamlined, and effective.

Prototyping for a PHI tool has been ongoing at NSSL for several years with forecaster testing at the Hazardous Weather Testbed. The most recent HWT iteration occurred in the Spring of 2014 with forecasters issuing probabilistic forecasts for radar--indicated hazards (tornado, wind, hail, and lightning) using a prototype web tool (Karstens et al. 2014a). It is proposed that efforts begin transferring the robust aspects of the prototype web tool code base, as determined by prior HWT testing and evaluation (Karstens et al. 2014b), into an operational setting, such as AWIPS II Hazard Services. Human factors expertise will be applied to the layout and functionality of the interface for PHI guidance and PHI grid generation in AWIPS II. Testing and evaluation of the AWIPS II Hazard Services tool would be conducted in the 2016 HWT Spring Experiment.

The projects listed in this facet build on each other to create Forecaster Tools for PHI.

4.A. PHI tool to Hazard Services

Project 4.A.1. Prototype development

Outcome(s): Experimental interface for rapid prototyping.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
1 - Top	4	150	600	1 2 3	2.A.1, 7

Project Details: The project continues development of a prototype PHI tool for rapid integration and testing of new concepts for generating PHI. Rapid prototyping allows for quick successes/failures through evaluation to understand which concepts work programmatically in the prototype, interactively with forecasters in the HWT, and skillfully/reliably through verification. It also stimulates progressive applied scientific research.

Some specific tasks required in this project include:

1. Continued support of prototype PHI tool stemming from prior development activities (SEED grant)
2. Integration of recommender guidance
3. Integration of "forecaster over-the-loop" concepts
4. Iterative design reviews with Human Factors experts
5. Testing and evaluation in HWT
6. Transferring of vetted concepts to Hazard Services interface
7. In out-years, continuation of earlier objectives, with eventual downsizing of prototype development efforts as concepts are implemented into Hazard Services

Project 4.A.2. AWIPS II / Hazard Services Infrastructure

Outcome(s): Implementation of ideas vetted through the prototype and HWT testing into AWIPS II / Hazard Services.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
1 - Top	6	250	1500	2 3 4	

Project Details: The project implements science / technology tested and proven in the PHI prototype tool in Hazard Services to allow full testing in AWIPS II. Required tasks include:

1. Development of numerous "recommenders" to interactively display guidance information to forecasters
2. Iterative evaluation of the interface by human factors experts
3. Testing and evaluation in the HWT

Project 4.A.3. Hazard Services Widgets

Outcome(s): Forecaster-friendly "widgets" in Hazard Services tools for multiple phenomena.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
3 - Mod.	2	150	300	4	3

Project Details: This project will create quick-use widgets in Hazard Services by which forecasters can quickly identify and "draw" probability fields for multiple phenomena at the same time. For example, a "supercell widget" swept across a probability grid would draw the tornado, hail, wind and flooding probabilities on their respective grids at the same time.

The goal of the project is to create "Threat Type Painter" widget for supercell, QLCS, derecho, and flooding events.

Issues/Questions:

1. May require new advances in AWIPS-II capabilities.

4.B. Ensure maximum PHI from minimal forecaster effort

Project 4.B.1. Human factors assessment in HWT

Outcome(s): Interface thoroughly tested and designed with extensive input from NWS forecasters prior to deployment.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	4	100	400	1 2 3 4	4.A.1

Project Details: Human factors assessments during the development and testing phases of the PHI interface are required to ensure that the software is intuitive to use by the majority of forecasters. Forecasters will work alongside software developers and human factors experts to provide extensive input on the design of interactive systems. Work to be completed includes:

1. Evaluation of prototype PHI tool concepts leading up to and during HWT testing
2. Evaluation of early Hazard Services PHI interface leading up to and during HWT testing
3. Continued evaluation of Hazard Services PHI interface as new methods and concepts are integrated.

Project 4.B.2. Addition of guidance information into PHI tool prototype

Outcome(s): Calibrated first-guess fields from MYRORSS, NWP, and other sources into PHI tool for use by forecasters.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	1	150	150	2 3 4	2

Project Details: The project brings first-guess probabilistic guidance from the MYRORSS climatology, NWP guidance (including Warn-on-Forecast), and other sources such as the UW-CI (Cintineo 2014) algorithm into the PHI tool prototype. The guidance provides a starting point for forecasters creating probabilistic output and to maintain consistency of probabilities among forecasters and forecast offices. Tasks include:

1. Integrate UW Satellite Prob Severe algorithm features
2. Based on HWT 2014 results, add reflectivity feature boundaries as default shape in PHI tool rather than oval shapes that estimate the extent of storm coverage
3. Integrate probabilities from MYRORSS storm severity, classification and environmental dataset
4. Incorporate guidance from storm-scale and mesoscale NWP

4.C. Refine "forecaster over the loop" processes for severe operations

Project 4.C.1. Forecaster over the loop

Outcome(s): Recommender based on forecasters grid modifications.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	3	200	600	3 4 5	2.A, 7

Project Details: Development and testing of methods that give forecasters the ability to quickly select and edit recommender guidance in ways that are intuitive and manageable to the forecaster and add value (skill / reliability) to the forecast. The project explores forecaster interaction with PHI including the ability to account for ground truth feedback in a Warn On Forecast paradigm. It will report on options for forecaster over the loop workflows as well as interaction feedback process. It establish recommenders based on forecasters' grid modifications (if X happens, then expect Y), and addresses the question: "Do forecasters modify the output probabilities or do they modify the input meteorological information since the output probabilities are already calibrated?" This is testable with MYRORSS data in the existing PHI tool.

Some specific tasks include:

1. Development of methods to incorporate guidance information into prototype PHI tool
2. Establish means of determining how much value the forecaster adds
3. Testing and evaluation performed in HWT
4. Implementation of vetted methods into Hazard Services

4.D. Use PHI to resolve County Warning Area (CWA) inconsistencies.

Project 4.D.1

Outcome(s): Effective approaches (best practices) for minimizing CWA inconsistencies in the application of PHI.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	2	75	150	4 5 6	3, 7

Project Details: This project will identify the cause of differences in forecasters' application of PHI and legacy warnings between CWAs and develop strategies to minimize or eliminate such inconsistencies.

The project includes these steps:

1. Quantify inter-CWA boundary inconsistencies and document their causes.
2. Compare any inconsistencies with the existing system.
3. Develop NWS policies, practices and training to address CWA inconsistencies.

Issues/Questions:

1. Requires NWS policy change to eliminate CWA boundary issues

Facet #5 (Usable Output) Areas of Emphasis

While initially retaining legacy watches/warnings – albeit in a refined manner – is a goal of FACETs, a more fundamental goal is to deliver a continuous, rapidly-updated stream of PHI at high spatial resolutions from days to seconds prior to an event. The power of FACETs is in the ability of recipients and value-adding enterprises to "mine" user-specific, actionable information from this high-resolution continuum of data. This data mining can serve a wide variety of displays, formats, and applications. This facet will describe several projects which will explore the means and media by which this can happen.

5.A. PHI-enabled alternatives to watch/warning information

Project 5.A.1. Develop a non-numeric means of communicating threat level(s)

Outcome(s): A threat-based color/icon (or other) scheme that is universally-adaptable and understandable.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	2	150	300	1	4, 6

Project Details: A system comparable to the European MeteoAlarm will be developed using the steps shown below. Significant SBES involvement and coordination with the Weather Enterprise will be needed.

1. Establish a prototype color/icon system across all hazards. Hire/Contract graphics designers to do so.
2. Collaborate with WMO to ensure consistency with evolving WMO recommended standards for hazards communication.
3. Conduct surveys of a broad spectrum of users, stakeholders and focus groups (e.g., NWC tours).
4. Identify user (not meteorological) thresholds for action along with recommended baselines" for how to develop personal probability thresholds.
5. Establish deterministic output for the general public to provide a "starting point" baseline.
6. Define "appropriate responses" to threat levels.
7. Establish a "crosswalk" between current WWA system and FACETs paradigm.

Issues/Questions:

1. Meteoalarm focus group example - data stratified for age, race, gender. Ten focus groups in study. Some folks were attached to the legacy products - not as ready to move on.
2. The extra area in the current warning system may be a safety net. How much can you trim before you start putting people in danger? (Another project?)
3. Requires coordination with Weather Enterprise, as each portion of the Enterprise can contribute their expertise to these goals.

Project 5.A.2. Risk Modeling

Outcome(s): Output from risk models that is fed by PHI.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	2	150	300	3 4 5 6	4, 6

Project Details: Working with social, behavioral, economic science (SBES) community, key risk models will be identified and/or developed to which PHI output can serve as primary input.

Some specific tasks required in this project include:

1. Identify prospective dynamic risk models and develop/test PHI input for them.
2. Work with risk assessment specialists and industry to optimize dynamic risk model performance based on PHI input.
3. Build web-based "risk maps" based on input from EM and others who do local risk assessment.
4. Establish a mechanism by which local WFOs can work with EMs to change risk probabilities as needed.
5. Incorporate climatologies of risk (e.g., Boston tornado response different than Oklahoma tornado response).

5.B. PHI-enabled media (NWR, phone apps, social media, broadcast media, etc.)

Project 5.B.1 PHI Through Legacy Systems

Outcome(s): Weather radio revised to serve as a medium for communicating PHI.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
3 - Mod.	3	150	450	4 5 6 7	6

Project Details: Develop methods for communicating PHI via legacy systems such as NOAA Weather Radio (NWR). Some specific tasks required in this project include:

1. Develop and test NWR communication of PHI.
2. Develop a baseline operation concept for PHI on NWR.
3. Develop a digital radio transmission prototype for PHI data.
4. Develop a prototype digital signal for NWR transmission.
5. Work with industry to develop a NWR with geolocation capability.

Project 5.B.4. PHI Through EM Functions

Outcome(s): PHI output compliant with FEMA emergency (EMS) communications and local siren policies/practices.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	2	100	200	4 5 6 7	5.E.1, 6

Project Details: Working closely with industry and EM partners, PHI output will be tested in a variety of media related to EM operations. This will require evaluation of new concepts and establishment of best practices in data delivery. Compare to 5.E.1.

Some specific tasks required in this project include:

1. Establish connection with impact catalog and GIS impacts databases. Demonstrate application.
2. Utilize the FCC Communications, Security, Resilience Interoperability Council (CSRIC) to ensure there is interoperability between different emergency systems.
3. Develop EM-relevant thresholds for action, based on regional difference.
4. Assist industry in establishing thresholds with their emergency services clients.

Issues/Questions:

1. Might need to adopt a pre-existing interoperable system rather than inventing something new.

5.C. PHI-enabled formats (graphical, GIS, textual, auditory, digital, USNG, etc.)

Project 5.C.1. PHI Format Standardization

Outcome(s): Standardized PHI data formats established for multi-media purposes.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	2	150	300	4 5	4, 5.D.1, 6

Project Details: The project is a coordinated one between numerous NOAA entities and the Weather Enterprise to develop and refine data format specifications for distribution. The Weather Enterprise has substantial expertise in the delivery of various product to end users developed and disseminated by NOAA and can thus provide valuable guidance in this process. Some specific tasks required in this project include:

1. Coordinate with AWI and vendors to determine most effective formats.
2. Vet proposed formats through NOAA Strategic Planning & Policy Office.
3. Send test data for a small group of vendors and use feedback to further refine specifications.
4. Co-develop display capabilities for media (tested in the HWT).
5. Establish a body that will adjudicate changes to operations with regard to FACETs. Environmental Information Services Working Group (EISWG) a possible candidate, working with the NWS Strategic Policy and Planning Office.

Issues/Questions:

1. This is a business risk for folks in industry. So, there needs to be an opportunity for representation.
2. Warning formatting, protocols, standards, etc., need to be agreed upon. Need to include consideration of all hazards - not just severe.

5.D. Communicating new information (urgency, confidence, range of possibilities, etc.)

Project 5.D.1. Develop means of communicating confidence, range of possibilities, etc.

Outcome(s): Forecaster confidence clearly communicated, along with range of possibilities.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
3 - Mod.	2	150	300	4 5 6 7	2.A.1, 2.C.1, 4, 6, 7

Project Details: This project will focus on experimentation of new ways to communicate forecaster confidences in ways that will be of value to end users.

Some specific tasks required in this project include:

1. Develop confidence components in the PHI Tool.
2. Develop prototype displays for confidence and variability communication.
3. Vet proposed concepts through NOAA Strategic Planning & Policy Office.
4. Test, evaluate and iterate with EM, media and industry.

5.E. Ensure focus on impacts

Project 5.E.1. Develop connection with Impact Catalog(s)

Outcome(s): PHI cross-correlated with NWS Impact Catalog and AWI sources, using PHI to drive impact output.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	2	75	150	4 5 6 7	2.B.3, 4, 6

Project Details: The NWS is developing an Impacts Catalog, consisting of known societal impacts of climate, water, and weather dependent events. Additionally, the AWI provides applications of impact information for commercial and private citizen interests. To determine the impact, one must determine risk on a local level, which requires partnerships with local government officials and businesses.

The project involves collaboration between NOAA and the Weather Enterprise to link PHI with sources of impact information.

Issues/Questions:

1. Some data sources may be proprietary
2. Political sensitivities exist and need to be understood/discussed.

Facet #6 (Effective Response) Areas of Emphasis

There are wide-ranging questions regarding "effective and appropriate response" that must be addressed in a research framework. This facet is where SBES integration would have the greatest impact, although contributions of these disciplines are essential in all facets of the threat forecasting process. What matters most is how the individual responds to the "stimuli" of the weather enterprise. Several of the projects described in this facet are related to and even included in the Weather Ready Nation Projects D, E and F ("Effects of False Alarms on Warning Recipients"; "Effects of Warning Channel, Content, and Context on Population Response"; and "Laboratory and Web Experiments on Warning Messages"; respectively) described by Lindell and Brooks (2012). Projects D and F are included as complete FACETs projects below.

6.A. Baselining Risk Response & Communication

Project 6.A.1. Baseline assessment legacy watch/warning response by "publics."

Outcome(s): Develop a baseline measure of public responsiveness to weather warnings; continuously monitor geospatial and temporal fluctuations in the measure so that we can systematically and objectively evaluate the impact of FACETs initiatives/products.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
1 - Top	6	200	1200	2 3 4 5 6 7	All

Project Details: FACETs is motivated by the idea that reinventing the NWS watch/warning paradigm will save lives and protect property by increasing and improving public responsiveness to information about extreme weather (i.e., watches and warnings). Thus, the ultimate success or failure of the project should, in part, be determined by systematically evaluating the extent to which FACETs initiatives/products accomplish this goal. This project endeavors to provide input for this evaluation by establishing a baseline (benchmark) measure of public responsiveness under the current NWS watch/warning paradigm and continuing to measure/monitor public responsiveness as FACETs initiatives/products are implemented. The data necessary for this measure will be collected by way of a scientific survey that is administered on an annual basis to a representative sample of the general public.

This task involved designing and annually administering the baseline survey.

Issues/Questions:

1. For this to work, data collection must begin prior to the implementation of FACETs initiatives/products. Systematic policy evaluation requires a baseline that is not contaminated by the policy being evaluated.

Project 6.A.2. Establish baseline of current user response (Ethnographic Study)

Outcome(s): Understand user response to risk communication through PHI (or legacy) information.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	2	150	300	2 3	5, 7

Project Details: The project is an ethnographic study to understand user response to risk communication and establish a baseline to compare against future changes brought about by FACETs.

Some specific tasks required in this project include:

1. Develop close relationships with families in regions of high risk; do this before the season of events. When event is likely, go embed with them. Observe their reactions, thoughts, in situ. Build model(s) of behaviors. It's one of the only ways to know for certain what people actually do.
2. Consider use of a virtual reality environment to simulate this activity, at first.
3. How much similarity across populations is there in individual behavior in the face of risk?
4. How much difference is there between populations in individual behavior in the face of risk? What are the factors that impact population differences?
5. Understandings of weather in different parts of the country

Issues/Questions:
1. Close connection to Facet 7 (verification of response).

Project 6.A.3. Identifying relevant research on risk response and uncertainty

Outcome(s): Mapping of key research findings to relevant operational/societal aspects of FACETs.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
3 - Mod.	1	100	100	1 2	5

Project Details: Conduct a comprehensive meta-analysis of all relevant literature. Danielle Nagele and Vankita Brown have started this review.

Steps include:

1. Connect/Identify applicable findings to key attributes and activities of FACETs.
2. Develop additional projects as a result of findings.

Issues/Questions:

1. See research bibliography in Section VII.

6.B. Behavior Modeling

Project 6.B.1. Laboratory & Web Experiments on Warning Messages (WRN Project F)

Outcome(s): (From Lindell and Brooks, 2012): An understanding of the "relationship between objective characteristics of a message and participants' subjective reactions to those messages."

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	1	350	350	3	2, 3, 4, 6.A.2

Project Details: From Lindell and Brooks (2012): "Project staff should carefully examine the types of warning messages that different sources have disseminated in past tornadoes."

Some specific tasks required in this project include:

1. Specify contextual variables such as the locations of the rest of the household and proximity to different levels of shelter in past severe storms.
2. With assistance from weather enterprise, present carefully-constructed messages to focus groups to determine how warning recipients are likely to attend to and interpret the elements of these messages, as well as how the message elements affect perceptions of risk (certainty, severity, immediacy, and duration of personal risk), stakeholders (perceived expertise, trustworthiness, and protection responsibility), and protective actions (especially efficacy in protecting people and barriers to implementation).
3. Some studies should also be conducted that include messages from peers—such as friends, relatives, neighbors, and coworkers—that conflict to varying degrees with information from authoritative sources.
4. Assess warning recipients' intentions of taking different protective actions and actual actions taken. Compare baseline of intentions to changes in behavior based on messaging.

Issues/Questions:

1. See research bibliography in Section VII.

Project 6.B.2. Behavioral modeling tools

Outcome(s): Tools to do multi-faceted behavioral modeling of scenarios long before events happen.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
3 - Mod.	4	150	600	4 5 6 7	5, 6.A.1

Project Details: The project examines the unifying risk, consequences of warning decisions and weather events, and impacts (has origins in effective analytical, academic rigor). Perception, cognition, and action are studied to build knowledge of interconnectedness of individual human processing and response. The project will evaluate and implement effective virtual reality environments in which behaviors can be measured through controlled case studies.

6.C. User Response to Weather Messages/Messaging

Project 6.C.1. Effects of False Alarms on Warning Recipients (WRN Project D)

Outcome(s): (From Lindell and Brooks, 2012): A better understanding of false alarm effects (a.) for forecasters to better balance the tradeoffs between the near-term and long-term effects of warnings on risk area populations; and (b.) for local emergency managers to overcome any tendencies toward decreased risk perception in geographical areas with high rates of tornado activity.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	1	350	350	3	5, 6.A.1

Project Details: This is a spin-off of Project 6.A.1a but it this focuses more on the psychological aspects. From Lindell and Brooks (2012): "...examination of the psychological processes by which people classify an outcome as a false alarm (which might be interpreted as an indication of a flawed forecast process) or a near miss (which might be interpreted as an indication of inherent uncertainty in the behavior of storm systems). Specifically, a warning should specify the location, intensity, and timing of tornado impact, so a false alarm is inherently a multidimensional variable rather than the unidimensional variable that it is commonly assumed to be (a warning might be accurate about the timing of tornado impact but not its location and intensity). Some specific tasks required in this project include:

1. Research on the dimensions of error to which risk area populations pay attention.
2. Research on false alarms to identify the effects of different warning frequencies (the number of warnings per year) by conducting studies in different areas of the country that vary in this respect. This project should also conduct qualitative research using techniques such as open-ended interviews that provide insights into warning recipients' conceptions of false alarms. This research should also seek to determine if there are individual differences in people's responses to false alarms/near misses that are attributable to cognitive heuristics and biases that could be overcome by improved knowledge of statistical principles."

Issues/Questions:

1. In-depth focus groups with people from different areas of the country will reveal vastly different perceptions of "false alarms." There is also a psychological dimension to false alarm perceptions, so psychological researchers must be part of this.

Project 6.C.2. Contingent Valuation of Tornado Warning Parameters (WRN Project K)

Outcome(s): Contingent valuation on how risk residents value different warning message parameters.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
3 - Mod.	3	150	450	2	5

Project Details: From Lindell and Brooks (2012): "...a stated preference study that examines the economic valuation of some subset of lead time, probability of detection, reduced false alarm rate, path forecast, tornado intensity, forward movement speed, and area warned."

The project is a contingent valuation study on two communities—one in a high tornado hazard area and the other in a medium tornado hazard area—whose residents provide a wide range of demographic characteristics, especially age, education, income, ethnicity, homeownership, and tenure in the community.

Project 6.C.3. PHI User Response Assessments

Outcome(s): A clear set of guidelines on end-user behavior based on interpretation of PHI.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	2	150	300	3	5, 6.A.1, 7

Project Details: Experiments conducted on PHI output in a variety of formats so as to establish some predictability of response. In short, this project will answer the question**:** What do people do with PHI when they see it? This is related to WRN "Project E" (Effects of Warning Channel, Content, and Context on Population Response) from Lindell and Brooks (2012). Specifically, "research is needed to characterize different warning technologies in terms of characteristics such as message specificity, speed of dissemination, susceptibility to distortion, and penetration of normal activities." It is closely related to Project 6.A.1a, but focuses on PHI.

Some specific tasks required in this project include:

1. Focus group and studies on individual responses to PHI communications using a broad spectrum of SBES disciplines (e.g., sociology, communications, psychology, etc.)
2. Measurements of the effects of messaging content on individual decisions.
3. Based on preceding results, design PHI output to:
    a. Help people acknowledge the risk level so they make informed decisions.
    b. Let them understand the cost/benefit of decisions-rational within their own constraints.
    c. Make appropriate (primary vs. derived) decisions.

Issues/Questions:

1. What are the contexts that shape individual behavior in the face of risk?

6.D Maximize use of (and response to) PHI

Project 6.D.1. Use of PHI in the Weather Enterprise

Outcome(s): Metrics and protocols to ensure the needs of the Weather Enterprise are being met with FACETs.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	3	100	300	3 4 5 6 7	5, 7

Project Details: Quantitative and qualitative metrics and systematic protocols (e.g., annual user meetings) to guide the effective implementation and use of FACETs among members of the Weather Enterprise.

Some specific tasks required in this project include:

1. Work with Weather Enterprise partners and sophisticated users to develop meaningful metrics and protocols for monitoring FACETs implementation.
2. Using SBES, look at public policy, public administration, and fields that focus more heavily on corporate/government institutional behavior.

Project 6.D.2. PHI Through Social Media

Outcome(s): Facebook, Twitter, etc. leveraged for effective response.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
4 - Low	3	100	300	4	6

Project Details: The project builds on investigative research at CASR about how social media is used during severe weather events.

Some specific tasks required in this project include:

1. Learn how people use social media information during severe weather.
2. Learn how people respond when they receive a false alarm
3. Develop a strategy for using social media to communicate PHI.
4. Establish NWS protocols based on findings

Project 6.D.3. Public Outreach/Education of FACETs

Outcome(s): Public understanding of output products based on PHI.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	3	100	300	5 6 7	6, 7

Project Details: NWS Outreach will need a PHI component to help public understand new products and/or changes to legacy products brought about by the results of FACETs research. A marketing team is necessary to inform people about how FACETs will change the message they hear via the NWS and media without any degradation of services and emphasizing the improvements.

Some methods include:
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1. Education and outreach, through the combined effort of the NWS and AWI, along with untapped resources such as Sea Grant, OKFIRST or NCFIRST.
2. Look at entry points to groups of people via social networks
3. Child education, with children educating their parents
4. Public in home vs. public outside (in public streets/library)
5. Understand who uses what technologies. Constantly ask “who is being left out?”
6. Research on effects of various educational paradigms into public safety effectiveness

Facet 7 Areas of Emphasis

FACETs (and PHI, specifically) will place forecasts and observations on the same coordinate system - a geospatial grid - allowing for new and better metrics such as Brier scores, false alarm duration, false alarm area, site-specific lead time, and site-specific end time. The projects described in this facet explore these changes and add another important component - the verification of effective response by PHI recipients. The end result of this facet will be methodologies which can result in the overall improvement of the FACETs processes.

7.A. Measure skill of PHI forecast

Project 7.A.1 Development of experimental verification methods and metrics

Outcome(s): Verification techniques for continuously updating high temporal (1 min) and spatial (1 km) resolution probabilistic forecasts.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	2	75	150	1	2, 3.A.1, 4, 7.B.1

Project Details: The legacy NWS storm reporting system, with it resulting data published in *Storm Data*, is largely dependent on warning system and its limitations are well-documented (e.g. Witt *et al.* 1998). Historically, one storm report within a warning, whether county-based or polygon-based, is verified for reporting purposes with one public report of severe weather. As the areas of these warnings can be quite large, covering hundreds of square miles, the resulting storm reports typically represent the entire warning coverage area with just one or two reports taken at specific location and time.

The project explores and develops new techniques for verifying high temporal and spatial resolution forecasts of hazards collected independently of the warning generation process, including but not limited to:

1. Location-based surveys, as in the Severe Hazards Analysis and Verification Experiment (SHAVE; Ortega et al. 2009)
2. Crowdsourced reports, as per the mPING experiment and phone application (Elmore *et al.* 2014)
3. New reporting techniques not yet defined, such as crowd-sourced photography
4. Taking advantages of local mesonet and micronet stations, possibly leveraging MADIS and other distribution systems
5. Using GIS datasets to determine the probability that an area is substantially populated or has a sufficient road network to expect weather reports
6. Enhancing reports of non-severe (null) events as well as severe events
7. Providing more accurate intensity information for events
8. Developing synthetic verification techniques based on remotely sensed data (project 7.B.1)
9. Collaboration among NOAA, FEMA, the Red Cross, a local officials to ensure a consistent method of data collection

Project 7.A.2 Measure skill of existing forecasts / warnings using PHI-compatible grid

Outcome(s): Baseline verification statistics for FACETs.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
2 - High	2	75	150	1	7.A.1, 7.B.1

Project Details: The projects examines the skill of legacy warnings and watches on a PHI-compatible grid using synthetic verification techniques. The project supplements Project 3.A.1 ("Storm characteristics and behaviors in legacy NWS warnings and watches"), but delves into the entire period of record for MYRORSS.

Specific items to examine include lead time at specific grid points, false alarm area, POD/FAR/CSI on the grid, and variations caused by populations density and other reasons.

7.B. Evaluate PHI and observed events on same spatial grid

Project 7.B.1 Synthetic Verification

Outcome(s): Techniques to use remotely sensed data to assist with verification of severe weather events.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
3 - Mod.	2	150	300	3 4 5 6 7	2, 7.A.1

Project Details: The project develops techniques for using remotely sensed data to quantify the location and intensity of an event as well as the likelihood that the event occurred in the absence of high-confidence spotter reports at the location.

Steps involved in the process may include:

1. Identify which data fields (MRMS, single radar data, satellite imagery, aerial photography, crowd-sourced photography, etc.) are useful in developing synthetic verification grids
2. Determine the goodness of data fields and the confidence that severe weather occurred when certain remotely-sensed criteria are met
3. Determine when the remotely sensed verification is most useful and when it is not
    a. where can information make up for low population density?
    b. where is radar / other coverage not adequate to make this a useful approach?
4. Translate spatial statistics into useful information for forecasters, such as "what is an acceptable false alarm rate given a certain environment or storm type?"

Issues/Questions:

1. Requires very good confidence estimates about the goodness of remotely sensed data fields.

7.C Measure end-user response to forecast

Project 7.C.1 Measure end-user response

Outcome(s): Standardized operating procedures and techniques for WFOs and independent verification agencies to collect user response to PHI.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
2 - High	3	150	450	4 5 6 7	5, 6.A.1

Project Details: This activity develops a method to measure the response of end users to data provided under the FACETs paradigm. This requires effective communications across disciplines between physical and social science.

The verification will validate variations on the questions:

1. Did the event affect me?
2. When did it start?
3. How bad did it get?
4. When did it end?
5. What did I do?

7.D. Develop new performance metrics

Project 7.D.1 Develop new performance metrics

Outcome(s): Statistically valid results suitable for system improvement and research.

Priority	*Length (Years)*	*Avg. Annual Cost ($K)*	*Est. Total Cost ($K)*	*Phases*	*Dependencies*
1 - Top	2	250	500	4 5 6 7	2, 6

Project Details: The project develops new performance metrics that measure not only the meteorological intensity of events (and non-events) but the impacts of the event (or non-event).

A few of these include:

1. quantitative verification of the meteorological aspects of the probabilities and how they are computed
2. Economic impact of events and warned non-events (insurance, disaster declarations, lost revenue, etc.)
3. Measurement of unnecessary interruptions to the daily lives of individuals and business and their impact on the credibility of the action message

7.E. Provide verification to customers / partners

Project 7.E.1 Provide verification to customers / partners

Outcome(s): Partner understanding of the value of probabilistic information and other outputs.

Priority	***Length (Years)***	***Avg. Annual Cost ($K)***	***Est. Total Cost ($K)***	***Phases***	***Dependencies***
3 - Mod.	2	50	100	4 5 6 7	6.A.1

Project Details: Work closely with partners (e.g. Weather Enterprise, Emergency Management, Media) as impacts-based verification techniques are developed and implemented. These partners have valuable insight into

The project involves presentation and discussion of verification research issues as well as collaboration on the development of performance metrics. A specialized verification conference could also be conducted to explore these issues.

APPENDIX B

This appendix organizes the Appendix A projects in a quasi-chronological fashion and by Phases. Each project is assigned to one of four broad tracks: "PS" for physical science, "S/W" for software, "SBES" for social/behavioral/economic sciences and "T&O" for training and outreach projects and activities. Figure B1 depicts the tracks, phases, initial (high priority) projects and their respective relationships to each other.

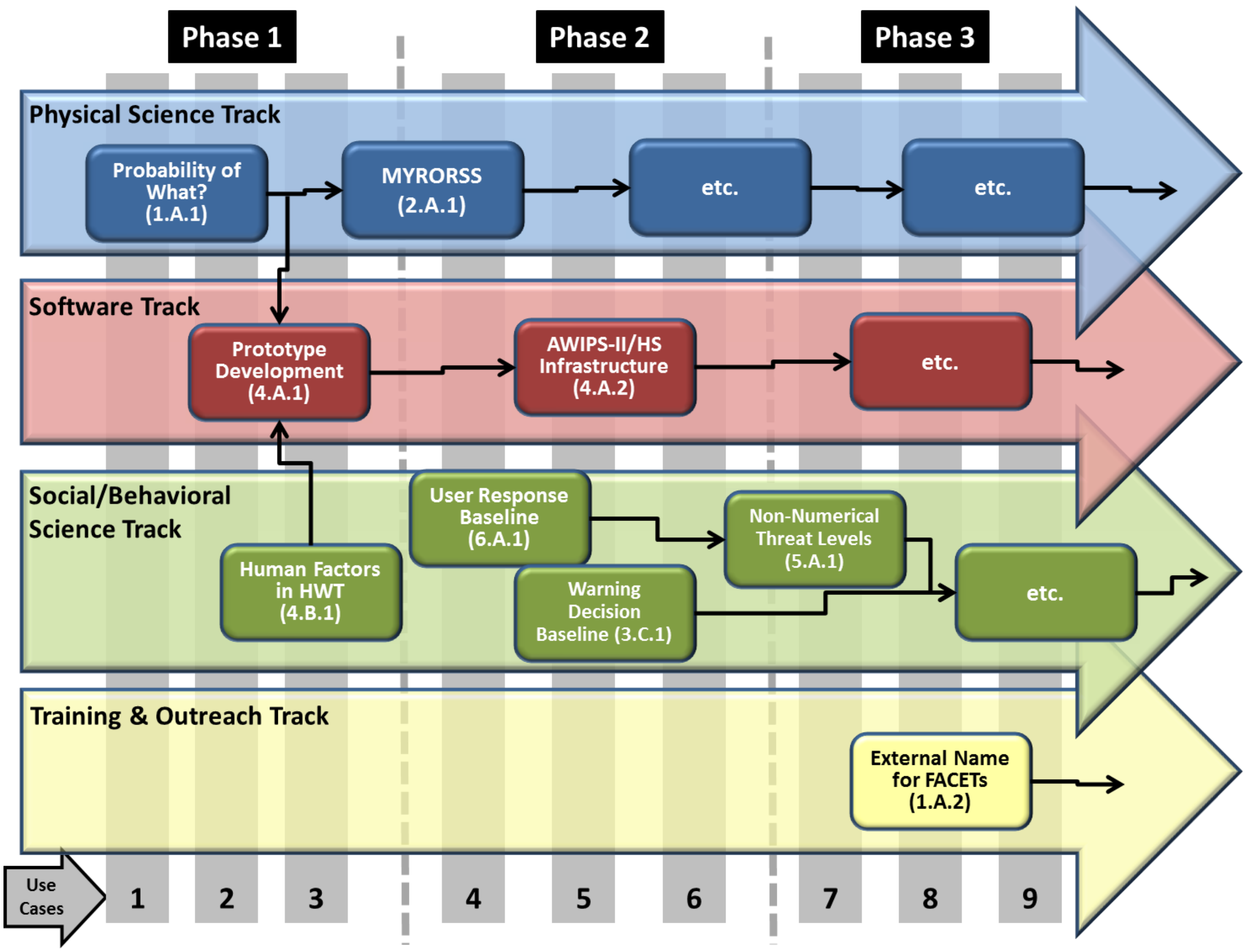

Figure B1. Depiction of the tracks, phases, Use Cases, initial projects and the relationship between them. A more comprehensive version of this figure will be used for planning and monitoring of FACETs progress.

Phase 1 Projects (Existing/Ongoing projects at the outset of the SSIP)

Project ID	Title	PS	S/W	SBES	T&O	Priority	$/Phase ($K)
	Use Cases	X	X	X	X	1 - Top	$50
1.A.1.	"Probability of What?"	X				1 - Top	$200
4.A.1.	Prototype development		X			1 - Top	$200
2.A.1.	MYRORSS	X				2 - High	$300
4.B.1.	Human factors / HWT			X		2 - High	$100
5.A.1.	Non-numeric threat levels			X		2 - High	$300
7.A.1	Experimental verification methods	X				2 - High	$150
7.A.2	Skill of existing warnings on grid	X				2 - High	$150
6.A.3.	Identify Relevant Research			X		3 - Mod.	$50
						TOTAL	**$1,500**

Phase 2 Projects (Critical baseline projects upon which future projects depend)

Project ID	Title	PS	S/W	SBES	T&O	Priority	$/Phase ($K)
	Use Cases	X	X	X	X	1 - Top	$50
3.C.1.	Warning Decision Baselining			X		1 - Top	$450
4.A.1.	Prototype development		X			1 - Top	$200
4.A.2.	AWIPS II / HS Infrastructure		X			1 - Top	$500
6.A.1.	Baseline user response			X		1 - Top	$200
2.A.1.	MYRORSS	X				2 - High	$300
2.A.3.	DP MRMS algorithms	X				2 - High	$200
2.B.1.	MYRORSS/ existing warnings	X				2 - High	$600
2.B.4.	Warn-on-Forecast Integration	X				2 - High	$100
4.B.1.	Human factors / HWT			X		2 - High	$100
4.B.2.	Add guidance info to prototype		X			2 - High	$50
2.A.2.	MYRORSS/Sat CI	X				3 - Mod.	$100
3.A.1.	Storms in legacy watch/warning	X				3 - Mod.	$200
6.A.2.	Baseline (entho) user response			X		3 - Mod.	$150
6.A.3.	Identify Relevant Research			X		3 - Mod.	$50
6.C.2.	*Contingent Val of TORs (WRN K)*			*X*		3 - Mod.	*$450*
						TOTAL	**$3,700**

Phase 3 Projects (Mid-Term projects not necessary at the outset)

Project ID	Title	PS	S/W	SBES	T&O	Priority	$/Phase ($K)
	Use Cases	X	X	X	X	1 - Top	$50
4.A.1.	Prototype development		X			1 - Top	$200
4.A.2.	AWIPS II / HS Infrastructure		X			1 - Top	$500
6.A.1.	Baseline user response			X		1 - Top	$200
2.A.1.	MYRORSS	X				2 - High	$300
2.A.3.	DP MRMS algorithms	X				2 - High	$200
2.B.2.	auto-PHI/legacy comparison	X				2 - High	$50
2.B.3.	FLASH concepts into FACETs	X	X			2 - High	$225
2.B.4.	Warn-on-Forecast Integration	X				2 - High	$100
2.C.1.	Severe wx/ enviro database	X				2 - High	$750
2.D.1.	SPC Transitional PHI	X	X	X		2 - High	$150
4.B.1.	Human factors / HWT			X		2 - High	$100
4.B.2.	Add guidance info to prototype		X			2 - High	$50
5.A.2.	Risk Modeling			X		2 - High	$75
6.C.3	PHI User Response Assessments			X		2 - High	$300
6.D.1.	Use of PHI in Wx Enterprise		X	X		2 - High	$60
2.A.2.	MYRORSS/Sat CI	X				3 - Mod.	$100
3.B.1.	Evaluation w & w/out human input	X	X	X		3 - Mod.	$150
4.C.1.	forecaster over the loop		X	X		3 - Mod.	$200
6.A.2.	Baseline (entho) user response			X		3 - Mod.	$150
6.B.1.	Experiments on Messages (WRN F)			X		3 - Mod.	$350
6.C.1.	Effects of False Alarms (WRN D)			X		3 - Mod.	$350
7.B.1	Synthetic Verification	X				3 - Mod.	$60
1.A.2.	The External Name				X	4 - Low	$50
						TOTAL	**$4,720**

Phase 4 Projects (Projects necessary before operational testing)

Project ID	Title	PS	S/W	SBES	T&O	Priority	$/Phase ($K)
	Use Cases	X	X	X	X	1 - Top	$50
4.A.2.	AWIPS II / HS Infrastructure		X			1 - Top	$500
6.A.1.	Baseline user response			X		1 - Top	$200
7.D.1	Develop new performance metrics	X	X	X		1 - Top	$125
2.A.1.	MYRORSS	X				2 - High	$300
2.A.3.	DP MRMS algorithms	X				2 - High	$200
2.B.2.	auto-PHI/legacy comparison	X				2 - High	$50
2.B.3.	FLASH concepts into FACETs	X	X			2 - High	$225
2.B.4.	Warn-on-Forecast Integration	X				2 - High	$100
4.B.1.	Human factors / HWT			X		2 - High	$100
4.B.2.	Add guidance info to prototype		X			2 - High	$50
4.D.1	CWA inconsistencies			X		2 - High	$50
5.A.2.	Risk Modeling			X		2 - High	$75
6.D.1.	Use of PHI in Wx Enterprise		X	X		2 - High	$60
7.C.1	Measure end-user response			X		2 - High	$113
2.A.2.	MYRORSS/Sat CI	X				3 - Mod.	$100
3.B.1.	Evaluation w & w/out human input	X	X	X		3 - Mod.	$150
4.A.3.	Hazard Services Widgets		X			3 - Mod.	$300
4.C.1.	forecaster over the loop		X	X		3 - Mod.	$200
5.B.1	PHI Through Legacy Systems		X			3 - Mod.	$113
5.B.4.	PHI Through EM Functions			X		3 - Mod.	$50
5.C.1.	PHI Format Standardization		X			3 - Mod.	$150
5.D.1.	Communicating new info		X	X		3 - Mod.	$75
5.E.1.	Connection w/ Impact Catalog(s)		X			3 - Mod.	$38
6.B.2.	Behavior modeling tools			X		3 - Mod.	$150
7.B.1	Synthetic Verification	X				3 - Mod.	$60
7.E.1	Customer / partner education / results			X		3 - Mod.	$25
6.D.2.	PHI Through Social Media			X		4 - Low	$300
						TOTAL	**$3,909**

Phase 5 Projects (Operational Test and Evaluation)

Project ID	Title	PS	S/W	SBES	T&O	Priority	$/Phase ($K)
	Use Cases	X	X	X	X	1 - Top	$50
3.C.2.	Extensive forecaster training				X	1 - Top	$300
6.A.1.	Baseline user response			X		1 - Top	$200
7.D.1	Develop new performance metrics	X	X	X		1 - Top	$125
4.D.1	CWA inconsistencies			X		2 - High	$50
5.A.2.	Risk Modeling			X		2 - High	$75
6.D.1.	Use of PHI in Wx Enterprise		X	X		2 - High	$60
7.C.1	Measure end-user response			X		2 - High	$113
4.C.1.	forecaster over the loop		X	X		3 - Mod.	$200
5.B.1	PHI Through Legacy Systems		X			3 - Mod.	$113
5.B.4.	PHI Through EM Functions			X		3 - Mod.	$50
5.C.1.	PHI Format Standardization		X			3 - Mod.	$150
5.D.1.	Communicating new info		X	X		3 - Mod.	$75
5.E.1.	Connection w/ Impact Catalog(s)		X			3 - Mod.	$38
6.B.2.	Behavior modeling tools			X		3 - Mod.	$150
6.D.3.	Public Outreach/Education of FACETs				X	3 - Mod.	$100
7.B.1	Synthetic Verification	X				3 - Mod.	$60
7.E.1	Customer / partner education / results			X		3 - Mod.	$25
						TOTAL	**$1,934**

Phase 6 Projects (Risk Reduction conducted at multiple NWS offices)

Project ID	Title	PS	S/W	SBES	T&O	Priority	$/Phase ($K)
	Use Cases	X	X	X	X	1 - Top	$50
3.C.2.	Extensive forecaster training				X	1 - Top	$300
6.A.1.	Baseline user response			X		1 - Top	$200
7.D.1	Develop new performance metrics	X	X	X		1 - Top	$125
4.D.1	CWA inconsistencies			X		2 - High	$50
5.A.2.	Risk Modeling			X		2 - High	$75
6.D.1.	Use of PHI in Wx Enterprise		X	X		2 - High	$60
7.C.1	Measure end-user response			X		2 - High	$113
5.B.1	PHI Through Legacy Systems		X			3 - Mod.	$113
5.B.4.	PHI Through EM Functions			X		3 - Mod.	$50
5.D.1.	Communicating new info		X	X		3 - Mod.	$75
5.E.1.	Connection w/ Impact Catalog(s)		X			3 - Mod.	$38
6.B.2.	Behavior modeling tools			X		3 - Mod.	$150
6.D.3.	Public Outreach/Education of FACETs				X	3 - Mod.	$100
7.B.1	Synthetic Verification	X				3 - Mod.	$60
7.E.1	Customer / partner education / results			X		3 - Mod.	$25
						TOTAL	**$1,584**

Phase 7 Projects (Full implementation)

Project ID	Title	PS	S/W	SBES	T&O	Priority	$/Phase ($K)
	Use Cases	X	X	X	X	1 - Top	$50
3.C.2.	Extensive forecaster training				X	1 - Top	$300
6.A.1.	Baseline user response			X		1 - Top	$200
7.D.1	Develop new performance metrics	X	X	X		1 - Top	$125
6.D.1.	Use of PHI in Wx Enterprise		X	X		2 - High	$60
7.C.1	Measure end-user response			X		2 - High	$113
5.B.1	PHI Through Legacy Systems		X			3 - Mod.	$113
5.B.4.	PHI Through EM Functions			X		3 - Mod.	$50
5.D.1.	Communicating new info		X	X		3 - Mod.	$75
5.E.1.	Connection w/ Impact Catalog(s)		X			3 - Mod.	$38
6.B.2.	Behavior modeling tools			X		3 - Mod.	$150
6.D.3.	Public Outreach/Education of FACETs				X	3 - Mod.	$100
7.B.1	Synthetic Verification	X				3 - Mod.	$60
7.E.1	Customer / partner education / results			X		3 - Mod.	$25
						TOTAL	**$1,459**

APPENDIX C

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