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A Systems Engineering Approach to Improving the National Weather Service

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by

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TABLE OF CONTENTS

INTRODUCTION

The National Weather Service (NWS) is a U.S federal organization responsible for ensuring the U.S is a weather-ready nation. As a weather-ready nation, the U.S expects to be prepared for and effectively respond to weather dependent events. Violent and disastrous weather events can unexpectedly threaten the lives and property of the nation; thus, it is important to maintain a strong and effective NWS system to mitigate the impact of those weather events.

> THE MISSION OF THE NWS IS TO PROVIDE WEATHER, WATER, AND CLIMATE DATA, FORECASTS AND WARNINGS FOR THE PROTECTION OF LIFE AND PROPERTY AND ENHANCEMENT OF THE NATIONAL ECONOMY.

A high-impact weather event can be categorized using two metrics: insurance payout total and death toll total. While the death toll measures the lives lost to the weather disaster, the insurance payouts quantify the impact to property damages. A weather event that reaches at least a billion dollars in insurance payouts and more than 10 deaths should be considered a high-impact weather event. As demonstrated by the figure below, there is an observed rise in high-impact weather events.

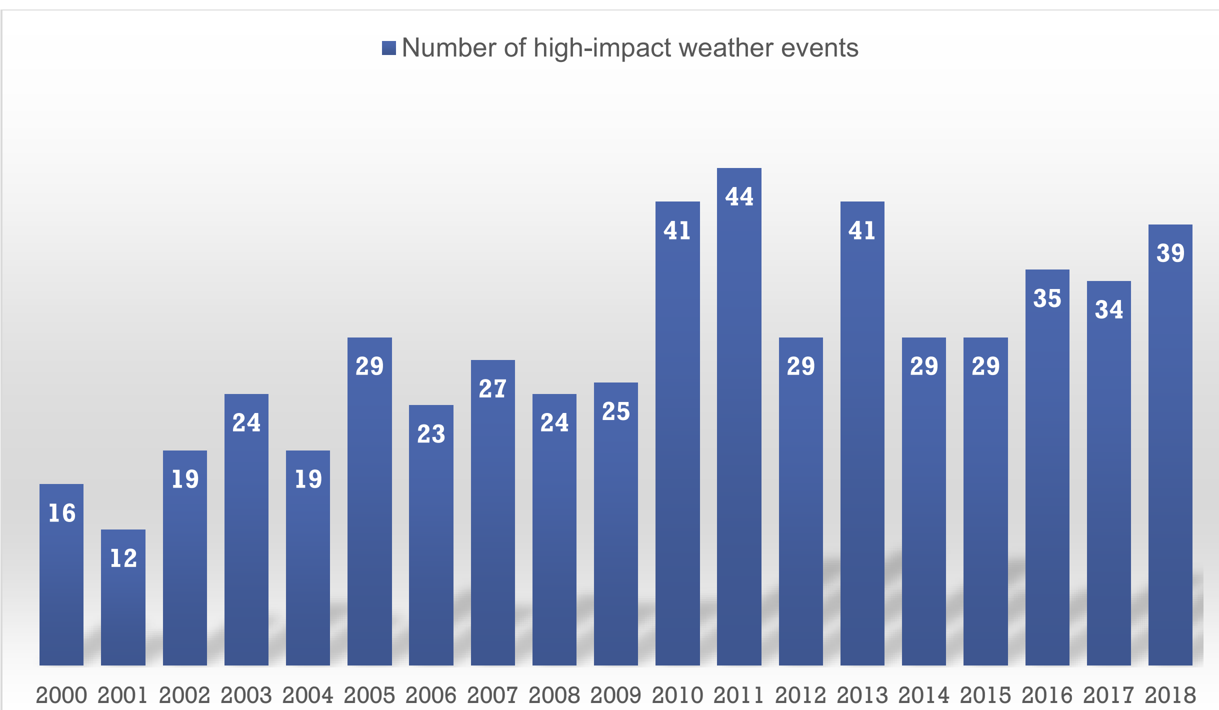


Figure 1. Number of high impact weather events between the years 2000 and 2018

The increases in population and material wealth over the last several decades are an important factor for higher damage potential. Additionally, the frequency of natural disasters may have increased due to climate change. Regardless of the exact cause, the rise in high-impact weather events suggests the need for a more effective NWS.

Investing in the improvement of the NWS system could potentially save hundreds of lives and billions of dollars in property damages every year. Investing in the improvement of the NWS is not only in the best interest of the U.S but it is also an ethical obligation. The U.S government is responsible for the safety of their people, so it is their obligation to ensure the best protection from threats such as natural disasters.

THE SYSTEMS ENGINEERING APPROACH

This paper will be guided by the systems engineering (S.E) approach to conclude on a strategic-plan for improving the NWS. The NWS organization will be treated as a system to benefit from the S.E methodology. As depicted by the V-Model below, the S.E approach focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem. However, design synthesis and system validation fall outside the scope of this project. This project will conclude with a defined optimal solution design, and a recommended implementation plan.

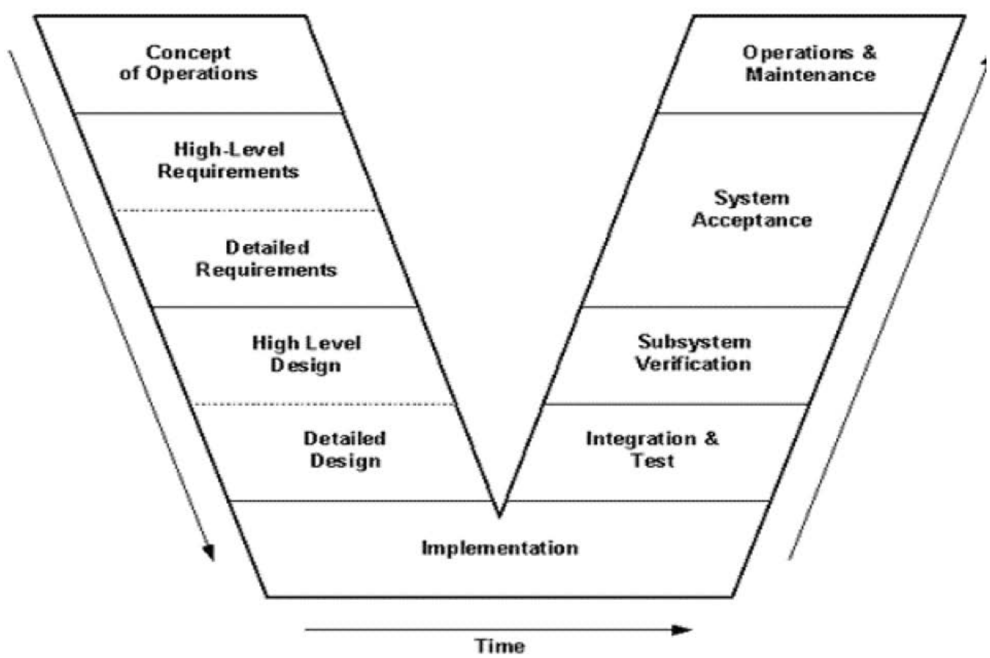


Figure 2. Systems Engineering V-Model

PROBLEM STATEMENT SUMMARY

Problem Statement – Mismanaged weather events can negatively impact the U.S economy, agriculture and destroy lives.

Project Goal – Improve the effectiveness of the NWS Emergency Response System to mitigate the impacts of dangerous weather events

Key Deliverables – A strategic plan to improve the NWS system for increased effectiveness

CONCEPT OF OPERATIONS

The concept of operations (ConOps) aims to describe the expected operation of the existing NWS organizational system in the terminology of its users and stakeholders. ConOps provides the needed information for the development of an appropriate NWS architecture that satisfies the identified stakeholder needs. Analyzing the current NWS system also helps identify the weaknesses and drawbacks that may be limiting the effectiveness of the NWS Emergency Response System.

THE CURRENT NWS SYSTEM

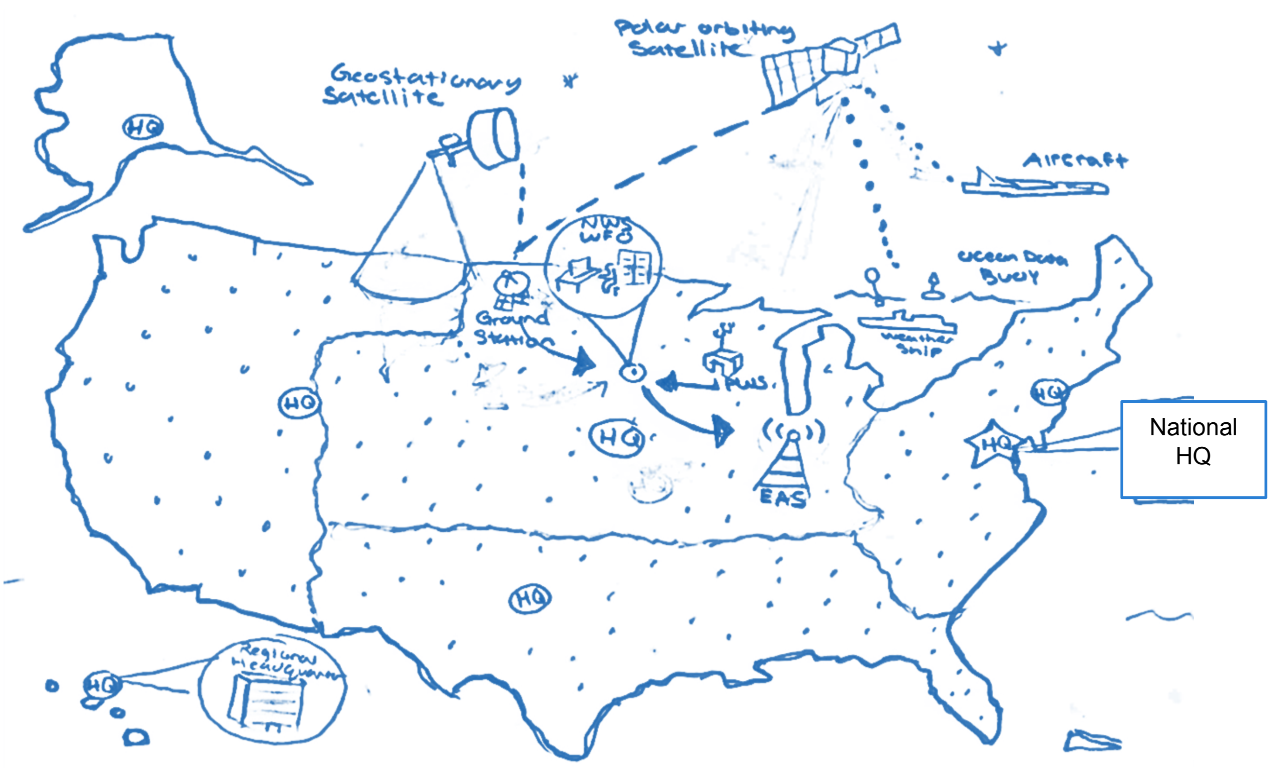


Figure 3. NWS Operational View 1

The NWS is comprised of the national headquarters and six regional offices. While the National Headquarters is responsible for overall management of the organization, the Regional Offices serve as administrative and operational support centers for the local forecast offices they serve in various sections of the country. The NWS operates 122 Weather Forecast Offices (WFOs) distributed across the country. The forecast office area of responsibility typically consists of 20 to 50 counties though some counties are split between offices based upon geographical features.

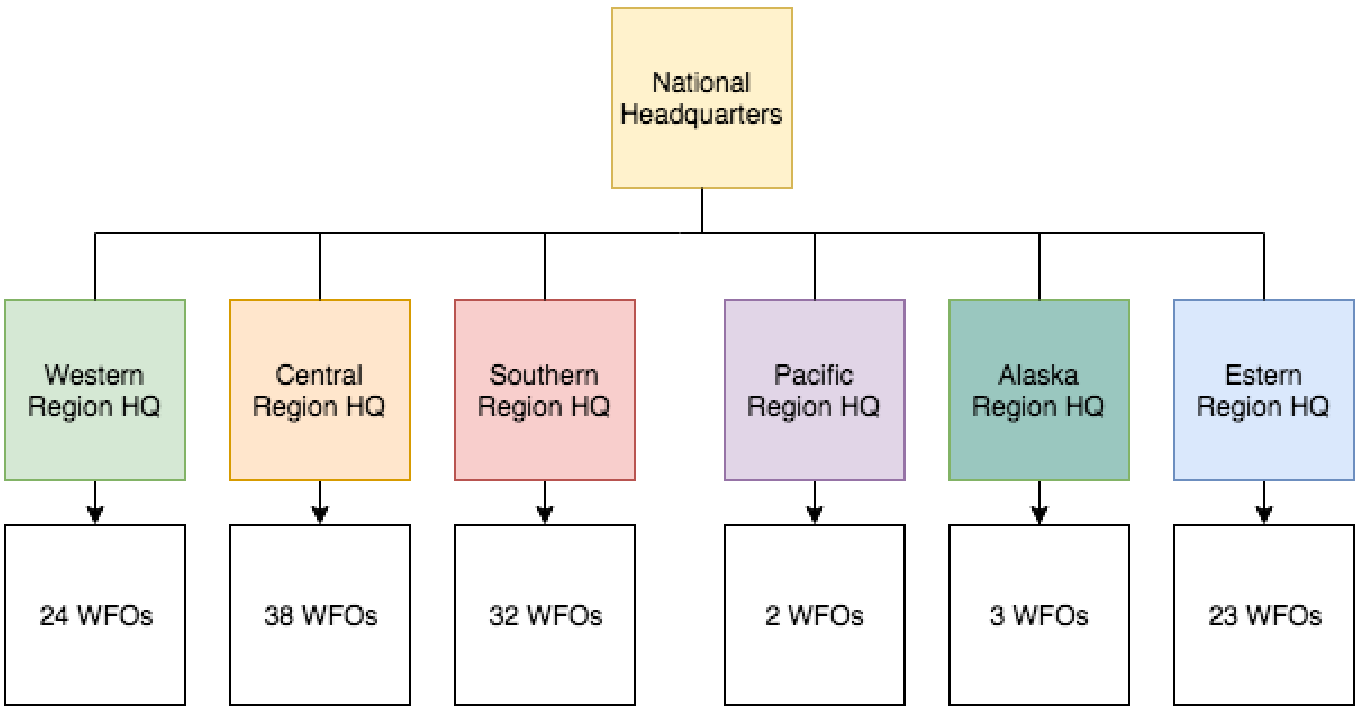


Figure 4. NWS High-level Organizational Structure

The figure above demonstrates an uneven distribution of WFOs among the Regional Headquarter Offices, suggesting an uneven workload among Regional Headquarter Offices. Furthermore, each region faces different weather hazards due to geographical differences. Considerations such as the geographical differences and varied workload contribute to the expected operational activities of each Regional Headquarter. Thus, each regional headquarter may have to maintain a different organizational structure to better serve their unique operational activities. In contrast, the NWS aims to evenly distribute the WFOs across the nation to ensure similar workloads among WFOs. Although WFOs are likely to face different weather hazards, every office aims to protect the lives and property of their assigned counties, which require similar operational activities.

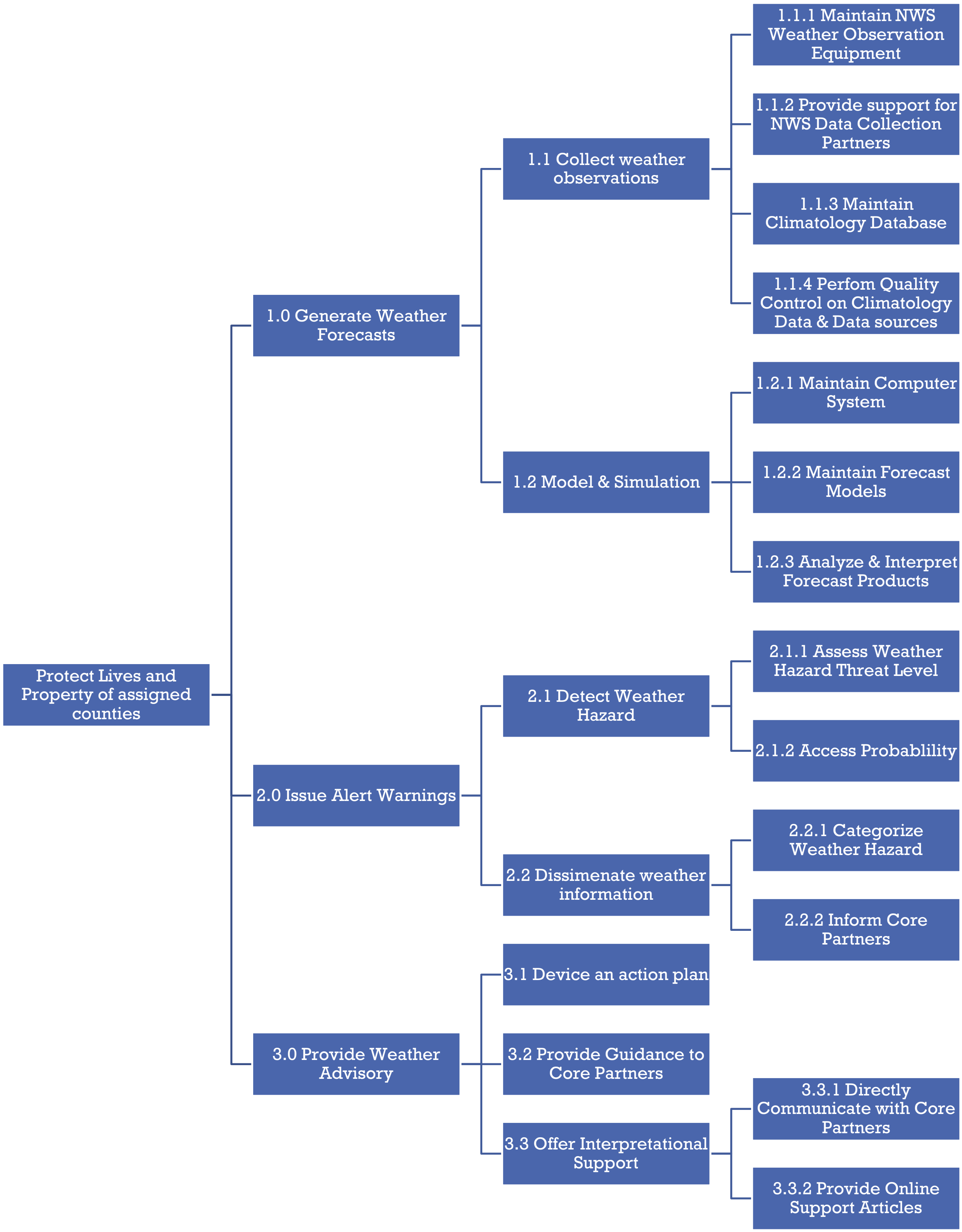


Figure 5. NWS WFO Operational Activity Diagram

In support of the expected operational activities, the WFOs maintain the following roles:

Role	Responsibilities
Meteorologist in Charge (MIC)	Manages all aspects of the office program in accordance with the NWS policies
Warning Coordinator Meteorologist (WCM)	Act as a liaison between the NWS and all local customers of NWS products and services in the County Warning Area
Science Operations Officer (SOO)	A Technical director and principal scientific advisor to the MIC and the WFO staff. The SOO is also expected to keep up with recent scientific advances in the fields of meteorology and hydrology as they relate to improving the operations of the WFO program. Also involved in training.
Data Acquisition Program manager (DAPM)	Manages data network activities for the WFO, which includes collecting, quality controlling and disseminating hydrometeorological data to support the hydrology program of the office. The DAPM ensures quality control measures are in place for all hydrometeorological data sources in the WFO.
Electronic Systems Analyst (ESA)	The ESA manages the computer systems (hardware and software) for the office.
Meteorological Team	The METs on station produce all operational products for the WFO, such as all routine and non-routine forecasts, warnings, and statements, including hydrologic products.

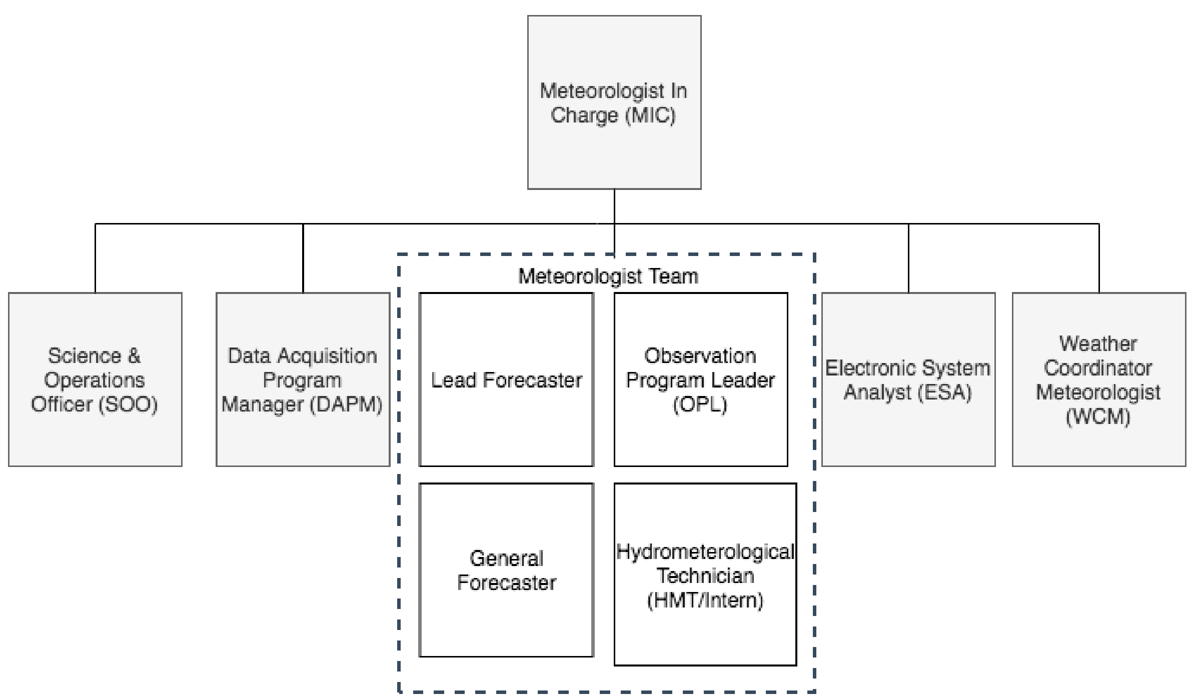
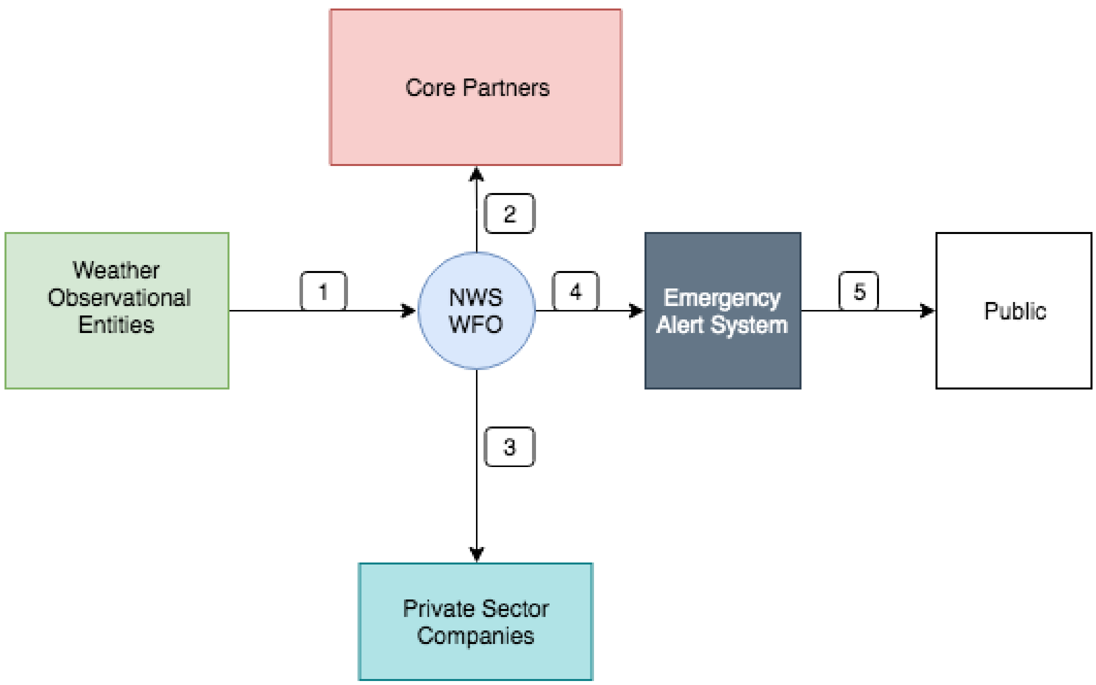


Figure 6. NWS WFO Organizational Structure

As demonstrated by the figure above, the team of meteorologist includes different roles that all contribute to the development of forecasts, warnings and statements. While the flat structure present in the meteorologist team allows for quicker decision making and encourages collaboration, it also encourages an argumentative workflow. The lack of leadership could often lead to duplicated efforts in producing and interpreting weather forecasts. Improving the workflow efficiency is essential for providing timely weather forecast and alerts.

STAKEHOLDER IDENTIFICATION

The stakeholders of the NWS are the people and organizations that interact with the operations and products produced by the NWS. The figures below demonstrate the external entities that directly interact with the NWS and their needs.



Weather Observation Entities	External entities capable of collecting climatology data such as satellite imagery, weather radar data, and ground weather observations	e.g COOP Stations, Personal Weather Stations, Commercial Airports…
Core Partners	Organizations expected to react, lead, or coordinate in the case of a weather emergency	e.g Government Offices, Emergency Management Community…
Private Sector Companies	Private companies that depend on or benefit from NWS products	e.g Insurance Companies, Private Weather Companies…

Figure 7. NWS Context Diagram

Need Line	Provider	Consumer	Description
1	Weather Observation Entities	NWS WFO	Raw Climatology Data
2	NWS WFO	Core Partners	Guidance & Support
3	NWS WFO	Private Sector Companies	Weather Forecasts
4	NWS WFO	Emergency Alert System	Alert Messages
5	Emergency Alert System	Public	Alert Messages

Figure 8. NWS OV-3

STAKEHOLDER NEEDS

Stakeholder	Needs	Importance
Core Partner	• Action driven statements • Guidance & support during weather disasters • Accessible action plans	The core partners are responsible for coordinating the resources and people during a weather disaster; therefore, the NWS must effectively guide and advise them during weather disasters to minimize impact
Private Sector Companies	• Accurate weather forecasts daily • Interpretational support	As part of the mission of the NWS, the NWS focuses on enhancing the U.S economy by providing supporting weather information to weather dependent businesses
General Public	• Immediate & descriptive emergency alert messages • Support and guidance during weather disasters	The general public requires immediate and descriptive alerts during weather forecasts to prepare and protect themselves and their property against weather events.

SYSTEM REQUIREMENTS

An optimal solution to improving the NWS system would aim to most effectively satisfy the stakeholder needs. It may not be possible to serve the needs of every stakeholder, but the desired solution should prioritize serving the most important stakeholder needs. As an attempt to design an optimal solution, stakeholder needs are translated into system requirements, as demonstrated by the figure below.

HIGH-LEVEL REQUIREMENTS

System Requirement	Acceptance test
System shall be able to communicate with core partners 99.9% of the time	Failover test on core partner communication system
System shall analyze weather forecasts with a total of 90% accuracy	Comparative testing between forecasted values and actual values
System shall deliver weather forecasts at least once a day to private sector companies	Unit test demonstrating the capability of sending weather forecasts to a familiar private sector company
System shall allow communication with private sector companies at least twice a day	Demonstration test of communication capabilities between private sector companies and NWS
System shall communicate a descriptive emergency alert messages in less than 5 minutes	Demonstration test of an initiated emergency alert message combined with an analysis of the average setup/process time
System shall be available to the general public 99.0% of the time	Failover test on public communication system

DETAILED DESIGN REQUIREMENTS

High level system requirements must be decomposed into quantifiable detailed design requirements so as to effectively guide engineers in the design of an appropriate system solution. The figure below demonstrates the decomposition of an important subset of system requirements.

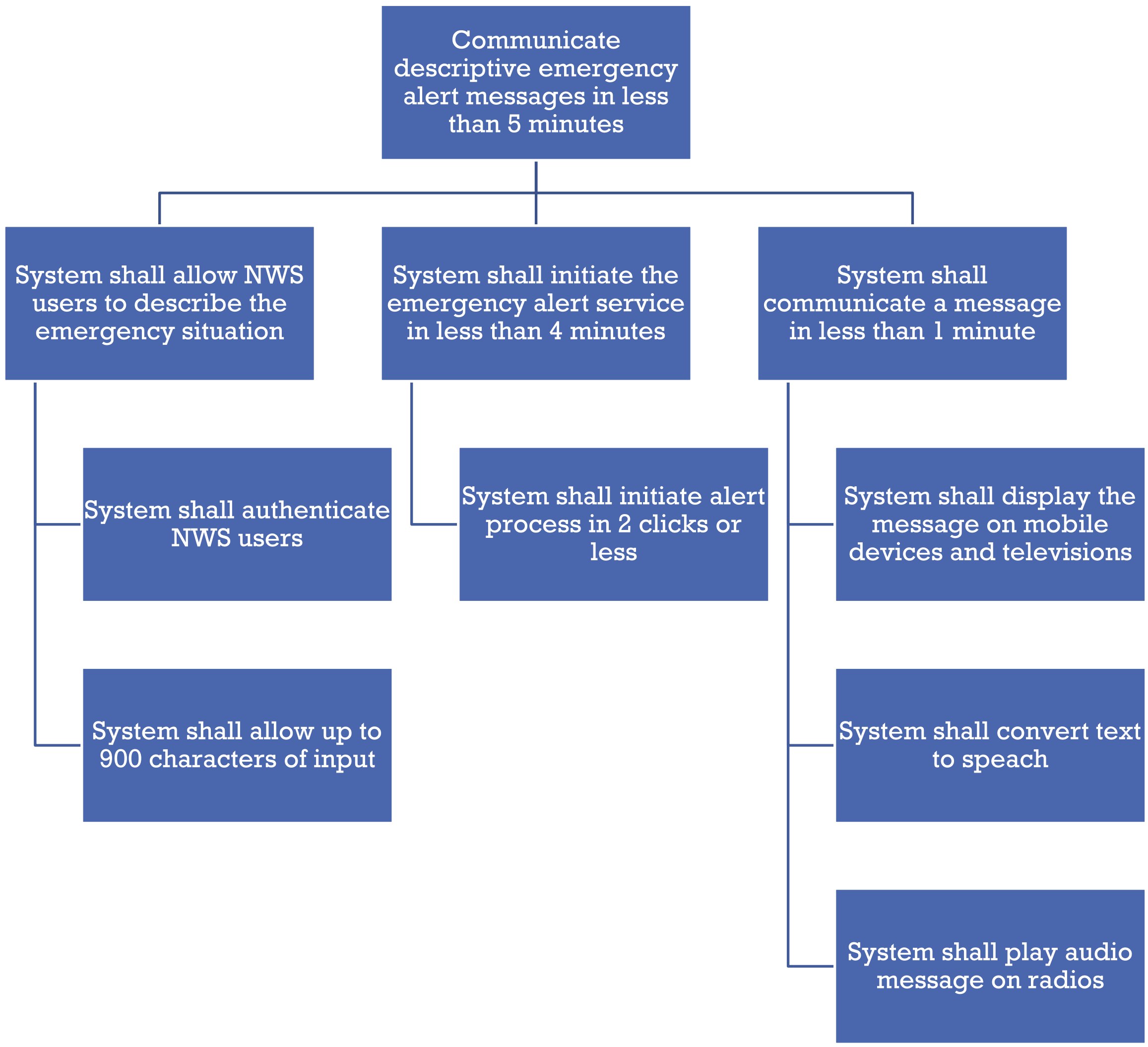


Figure 9. NWS SV-4

EXPLORING POSSIBLE SOLUTIONS

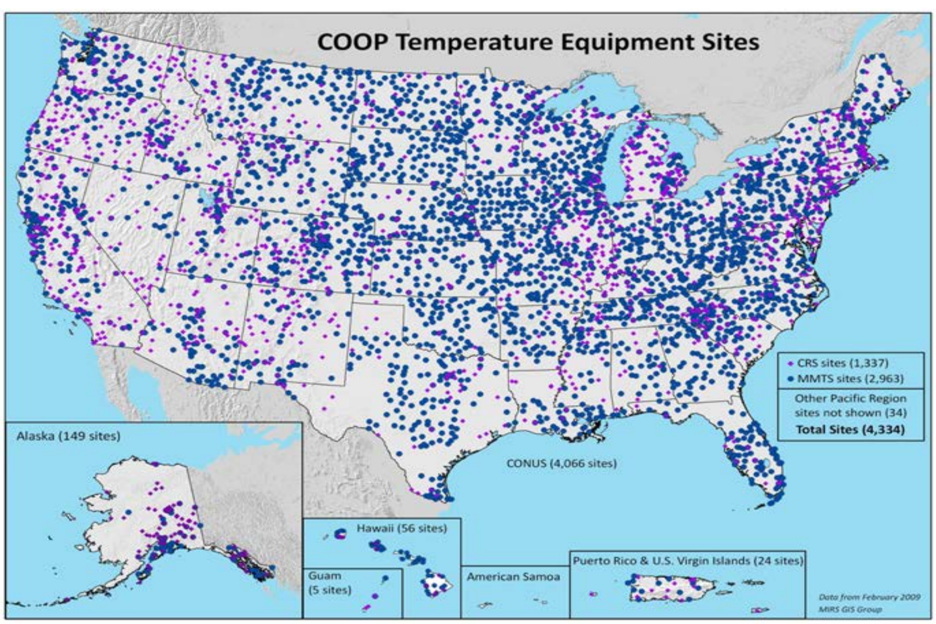
Proposing applicable solutions to a problem can be challenging because it requires a lot of imagination. One way to explore possible solutions for the NWS would be to look at its history and identify the factors that contributed to its initial rise. By determining the main factors that contributed to its success, solutions of the same characteristics could be explored.

WHY DID THE NWS INITIALLY SUCCEED?

The NWS was initially developed to protect U.S citizens from weather disasters. Efforts by the U.S to better understand and protect its residents from environmental dangers date as far back as 1807 when Thomas Jefferson created the Survey of the Coast. The organization was the official chart maker of the United States and its mission was to provide nautical charts to the American maritime community for safe passage into American ports and along the coastline. In addition to keeping ships safe and informed, the early charting system helped protect marine life. The Survey of the Coast served as a basis for other governmental agencies to serve the expanding need for environmental services. In 1870, the U.S army established the weather bureau, which started practicing basic weather forecasting to aid military operations. Weather forecasts proved to be useful for activities beyond military use, such as agriculture and aviation, and the weather bureau evolved into the NOAA's National Weather Service. With government funding, the NWS was able to create an organization focused on protecting lives and property.

NWS did not succeed with financial support alone. In fact, much of its success could be attributed on its adoption of technological advances. These technical advances could be categorized into two major categories, those that helped strengthen the communication network, and those that helped increase the accuracy of weather forecasts.

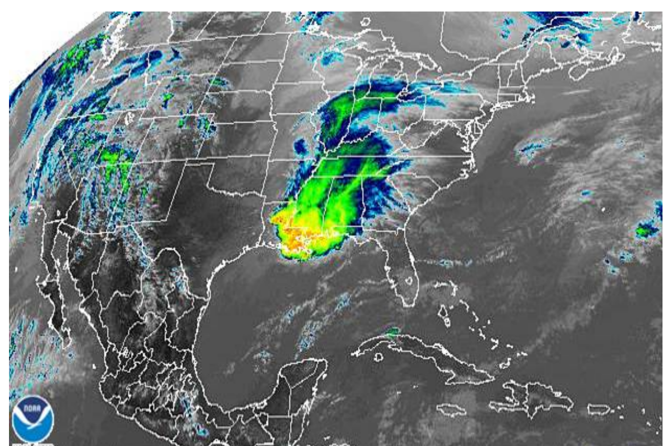
The first piece of technology that was capable of creating a country wide communication network was the telegraph. When the telegraph was introduced to the early stages of the Weather Bureau, military stations were able to record meteorological and communicate them to a central location.



The communication network was a crucial part to the Weather Bureau's operational activities. Additionally, it allowed the aggregation of weather observations from different sources. The communication network was able to quickly expand to include warships, foreign commercial ships, and volunteers around the country. Today, many operate a personal weather station and volunteer to record and share their weather observations with the NWS. There are 4 major volunteer programs which allow citizens to provide weather observations to the NWS, but the best well known is COOP. COOP is the oldest observer program and it is run by the NWS.

A strong communication network within the NWS is vital as it allows the collection of weather data that is necessary for generating weather forecasts. Similarly, the communication between its partners is necessary to be able to disseminate important weather information to those that need it. However, there does not seem to be a standard tool that the NWS uses today for either type of communication. Which could suggest that there is room for improvement in that area.

Much of the value of the NWS is based on the accuracy of their weather forecasts. Weather forecasting involves making predictions based on the observed current and historical atmospheric conditions and generating accurate weather forecasts is dependent on the accuracy and completeness of the collected weather observations. Therefore, tools that expanded the reach of observable atmospheric conditions directly impacted the accuracy of weather forecasts. One example is the use of meteorological satellites, which helps monitor large scale and severe weather events. The NOAA's system includes 16 satellites that are used to keep watch over the nation by providing scientific information and alerting the organization of any natural disasters such as fire, volcano eruptions or hurricanes.



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Today, accurate weather forecasts also heavily rely on the power of numerical weather prediction methods. Powerful mathematical forecasting algorithms are responsible for converting all the observed and recorded atmospheric conditions into weather forecasts. During the 20th century, NWS saw true advances with the increased computational power at its disposal. In fact, after the use of computer models, weather forecasting accuracy increased exponentially.

DEFINING A SOLUTION SPACE

As history shows, the rise of the NWS stems from three major components:

- Financial Support – The U.S continuous to fund and supports the National Weather Service. Both the financial support and guidance allows the NWS to exist while striving to provide an excellent weather service that prioritizes the safety of the people. This also allows volunteer programs such as COOP to exist and support the NWS in gathering weather observations.
- A Strong Communication Network – A strong communication network is essential for the NWS to generate accurate weather forecasts and disseminate the information as quickly and effectively as possible. Additionally, communication and collaboration with the meteorological community and other WMO members allow the NWS to adopt more successful methodologies proven by other entities.
- Science & Technological Advances – Breakthroughs in meteorological research, and an advancement in computational power increased the accuracy of weather forecasts. Other technological advances such as satellites also expanded the reach of the possible NWS weather observations. Over the past decades, the accuracy has actually increased exponentially, and it will continue to improve through the adoption of more technological advances and research.

Inspired by the initial success of the NWS, a promising solution space would be focused on strengthening the communication within NWS, improving the communication between NWS and its partners, and promoting the NWS's capability of incorporating new technologies.

An organization's performance is limited by its architecture and resources such as technology and tools. The organizational structure directly impacts workflow and consequently its efficiency. In the case of the NWS, timeliness is a top priority because every moment is crucial during an emergency weather event. Rearchitecting the NWS for optimal performance could potentially give more lead time to threatened areas. Additionally, the available resources to the NWS not only determines the accuracy of the generated forecasts but also its reach and ability to disseminate important information.

As an attempt to improve the performance of the NWS, the organization could be restructured, or a new tool could be developed to facilitate the organization's capability of reaching these goals. Both solutions will be explored and developed to achieve the system requirements that were previously defined.

HIGH LEVEL DESIGN ALTERNATIVES

ALTERNATIVE 1: DEVELOP A COLLABORATION & COMMUNICATION TOOL

A possible solution to improve the performance of the NWS is to design a new tool that could strengthen the intra and inter-communication of the NWS using software architecture techniques. Software architecture (S.A) is a discipline that aids in the design and structure of software systems while focusing on enhancing selected quality attributes of the system. There are many existing collaboration & communication tools, but with system architecting, a tool can be developed customized to the needs of NWS while focusing on enhancing the most prioritized system quality attributes. Just as the use of new tools in the past have improved the performance of the NWS, a superior collaboration & communication tool has the potential of doing the same.

QUALITY ATTRIBUTES

The important quality attributes (QAs) are those that will facilitate the NWS in accomplishing its mission. The following figure lists the QAs that the tool should be architected to enhance. For every enhanced QA there is always a counter QA that is being compromised in a system. Therefore, each QA is ranked by importance to aid in the trade-off decisions between QAs during the design process.

QA	Importance	Measure
Fault Tolerance	Communication during an extreme weather event is crucial since the NWS is responsible for alerting and advising its partners during those events. Therefore, the tool will need to be able to operate even in harsh weather.	Systems should be able to withstand strong winds and heavy rain.
Timeliness	During a natural disaster, every minute counts. Allowing the NWS to communicate as quickly as possible would give authorities more time to react.	NWS offices should be able to connect with one another and with external entities in seconds.
Usability	Dissemination of important weather information is not enough. Partners should be able to understand how to use the tool and interpret the displayed information.	Partner users should either be able to interpret weather information or quickly connect with an NWS representative for clarification.
Interoperability	NWS interacts with many different partner organizations, which have their own technical profile. Intercommunication will need to be able to handle different types of systems	System shall allow a very easy API setup between the most common technological infrastructures.

Modifiability	An identified success factor for the rise of NWS was its ability to incorporate and benefit from new technologies. Therefore, it is important for this tool to be able to change when necessary	Upgrades should be able to be made in a short period of time with little to no impact on daily operations
Scalability	As the network continues to expand its volunteer network, the NWS will need to handle more users	Systems should be able to handle large user increase without a noticeable throughput latency
Accuracy	Information that gets shared with partners needs to be accurate. False alarms could waste resources and lower system confidence	System should be accurate at least 90% of the time

USE CASES

The use case diagram below demonstrates the desired system functionality to serve the system requirements while focusing on promoting the desired QAs.

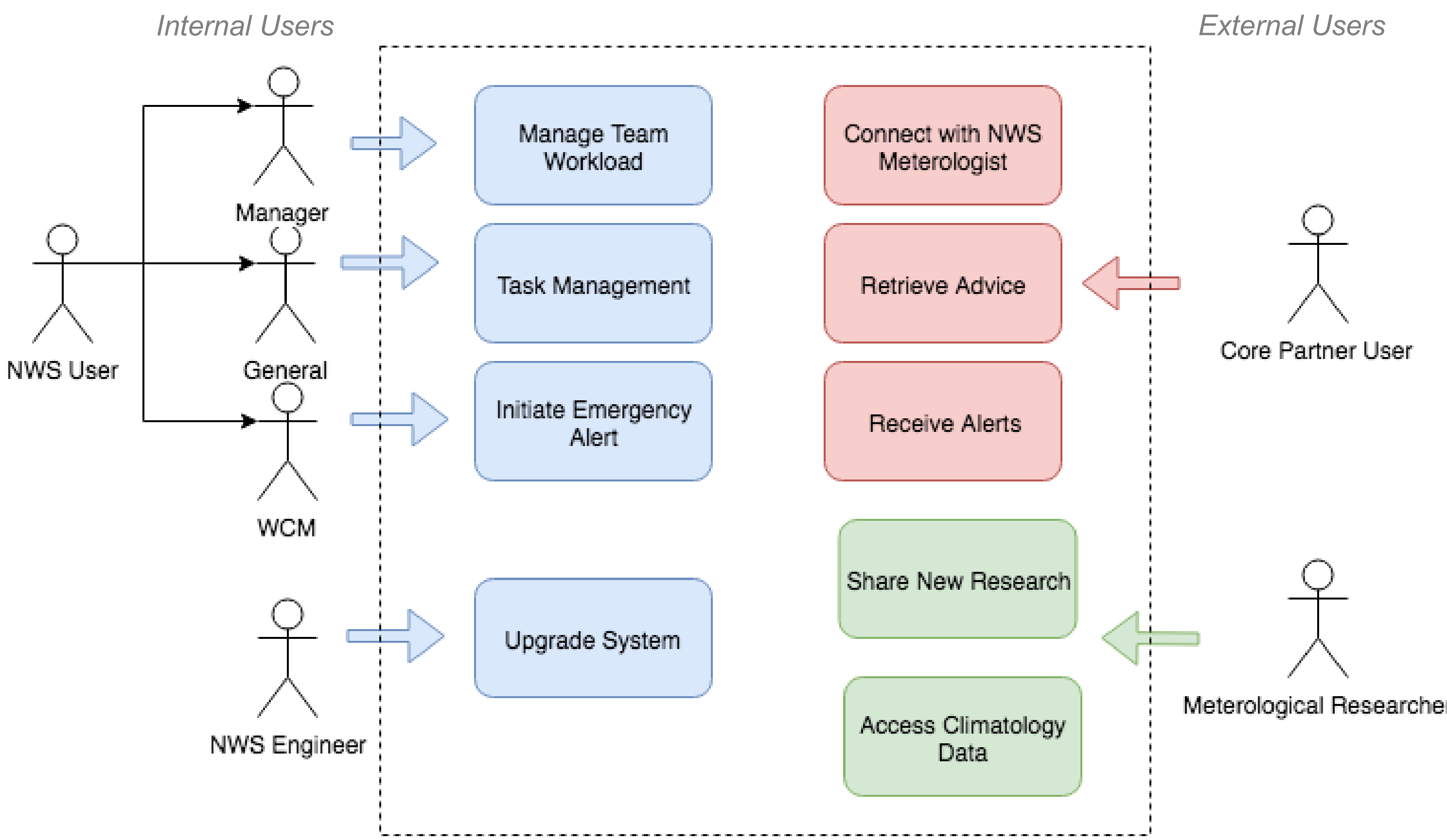

Figure 10. Collaborative and communication tool use case diagram

As described by the use case diagram, the system should focus on serving the needs of 4 main types of users. Each use case does not only support a necessary operational activity, but also enhances a desired QA.

NWS User Role

As an attempt to improve work efficiency within the meteorologist team, the system aims to provide a collaboration feature. The collaboration tool should allow managers to create, assign, and manage tasks. Increased collaboration should reduce duplicated forecasting efforts and promote team communication. The WCM should also be able to initiate Emergency Alert Messages through the system.

NWS Engineer Role

As demonstrated by the use case diagram, the system should allow for an NWS Engineer user to perform a system upgrade. This feature would promote modifiability within the system in hopes to efficiently and easily be able to upgrade the system to incorporate better technology and weather forecasting modeling techniques. A lot of time, money and effort is involved in adopting and standardizing a new tool within an organization. The tool not only needs to be developed, but users may need to be trained. Therefore, it is important that the tool gives engineers an easy way to upgrade the system when necessary instead of forcing them to completely rearchitect a new solution.

Core Partner User Role

The tool aims to create direct communication between core partners and NWS personnel to improve timeliness. The system should also allow core partners to request alert guidance, interpretation and support.

Meteorological Research Role

The use case diagram also demonstrates a meteorological research community user. This user should benefit the accuracy of the generated weather forecasts by allowing members of the meteorological community to share any new research finding directly with the NWS. The meteorological field is actively advancing, and the NWS would greatly benefit from those advances by having a direct connection to them. In return, the NWS would also cooperate in the meteorological research community by providing researchers access to raw climatology data to aid in their research.

Based on the expected capabilities demonstrated by the use case diagram, a software solution can be designed. System architecture aims to develop and represent an optimal system software design structure through the 4+1 architectural views: logical, development, process and physical. The use case diagram is the view that ties all of them together. Together they create a complete look on the software system structure.

The following component diagram can provide a basis for the logical, development, process and physical views, because it develops the system components needed to achieve the system functionality that was described in the use cases by identifying the first-class objects and then aggregating similar objects into components.

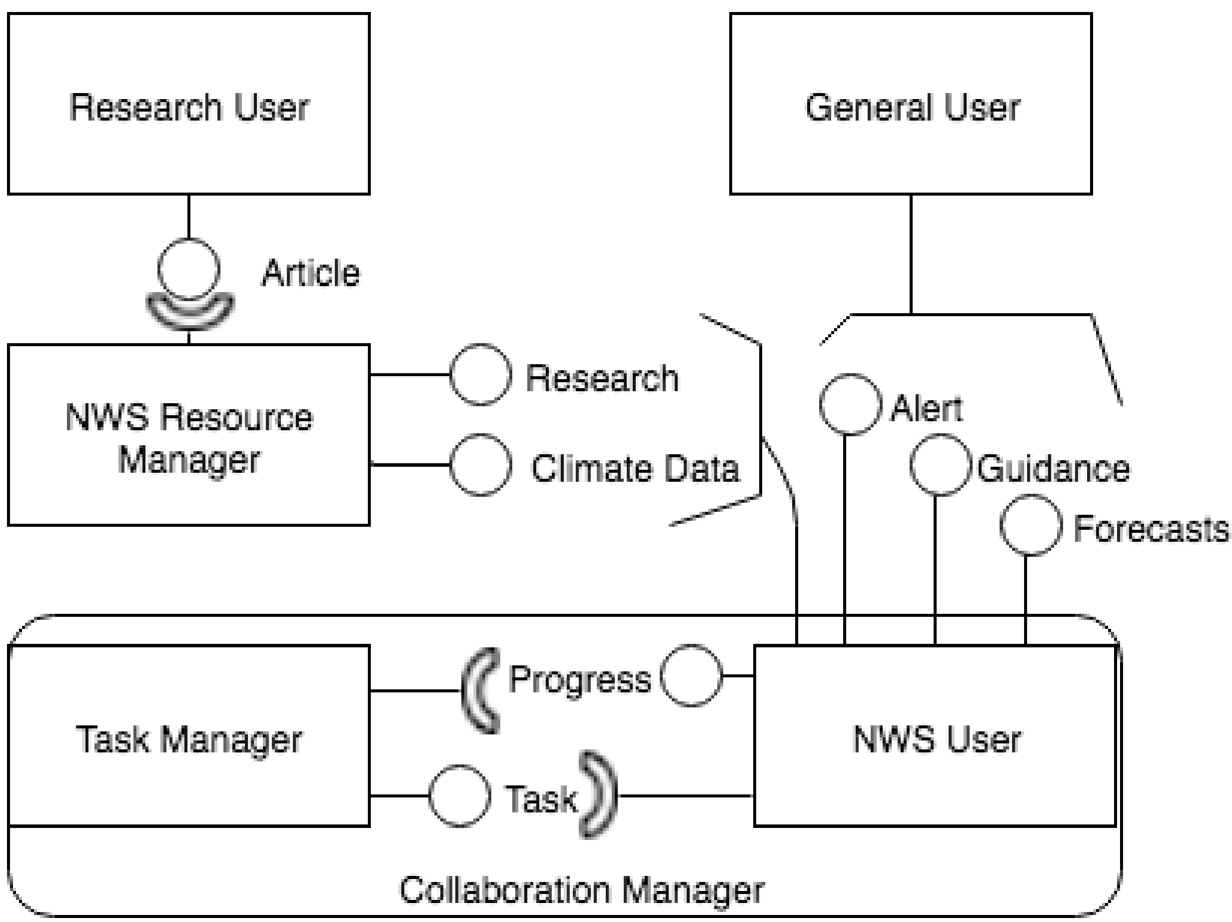

Figure 11. Component Diagram for a new NWS collaboration and communication tool

A RECOMMENDED CLOUD BASE SYSTEM

The recommended platform for this project would be a cloud-based architecture. The cloud's architecture is ideal for software systems where scalability and availability are a priority. The distributed structure provides the system facilitates horizontal or vertical scalability that will allow the system to handle an expanding user base. Additionally, the cloud has built in redundancy to ensure high-availability. As previously described, high-availability and fault tolerance is key for the software's performance. The physical view below shows how the cloud could be used to support the software solution:

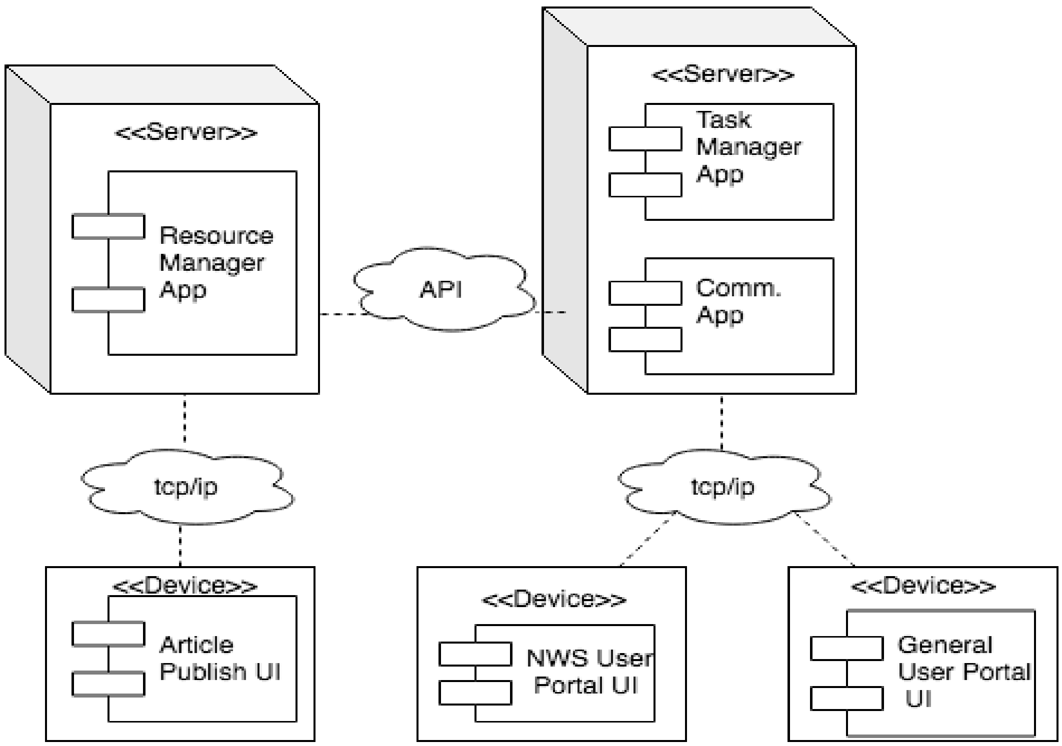

Figure 12. Deployment view for a new NWS collaboration and communication tool

The system can be further developed by a software architect to achieve an optimal design that can emphasize the needed QAs. The software system with those desired QAs will be better suited to serve the custom needs of the NWS users. A better collaboration and communication tool will facilitate the NWS's ability to disseminate accurate and action-driven information in a timely manner, which will increase the NWS's current performance. NWS could implement the software solution by redirecting a portion of their budget towards its development and user training.

ALTERNATIVE 2: REARCHITECT THE NWS ORGANIZATION

After analyzing the current system's operational activities, it is evident that most of the workload is dedicated to generating weather forecasts. However, the system is no longer able to compete with private weather forecast companies in generating weather forecasts. Furthermore, the NWS needs to focus on improving the emergency alert services to better protect lives and property from weather disasters. Therefore, a method of improving the NWS would be to rearchitect the NWS to prioritize the emergency alert service by eliminating their weather forecasting responsibilities. Instead, the NWS should rely on private weather forecast companies for more accurate and reliable weather forecasts. The efforts could be refocused on analyzing weather forecasts for weather hazards and meteorological research that could continue to improve the weather forecasting processes. Additionally, the NWS system should incorporate the Emergency Alert System to promote a closer relationship between them when necessary. The following figures demonstrates the proposed operational activity of a rearchitected NWS.

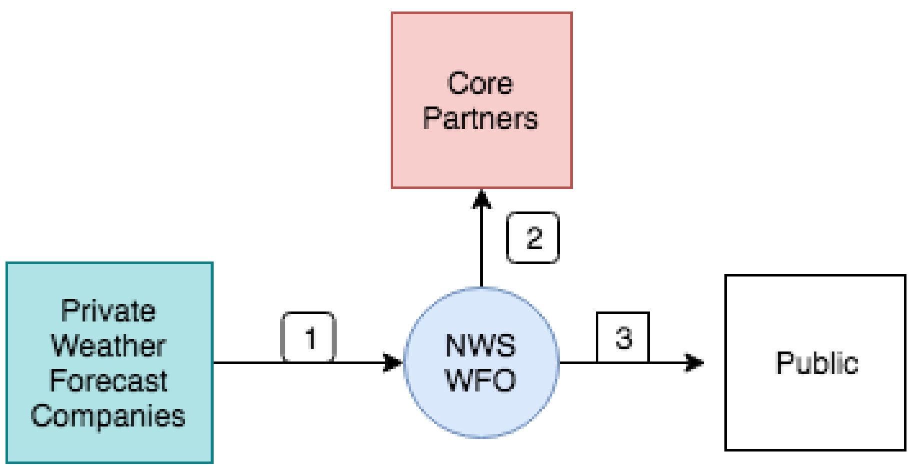

Figure 13. NWS OV-2

Need Line	Provider	Consumer	Description
1	Private Weather Forecast Properties	NWS WFO	Weather Forecasts
2	NWS WFO	Core Partners	Guidance & Support
3	NWS WFO	Public	Emergency Alert Messages

Figure 14. NWS OV-3

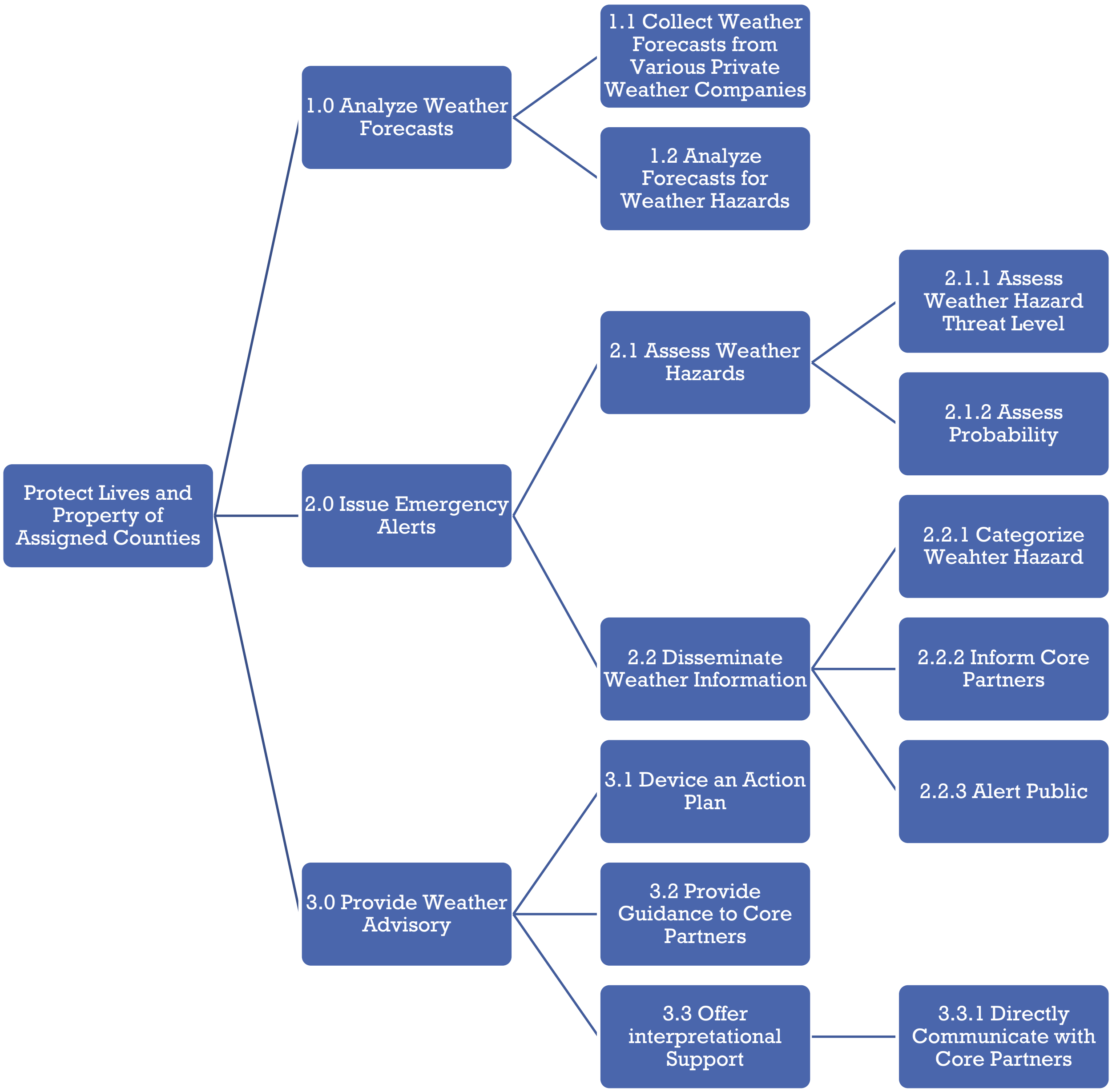

Figure 15. NWS OV-5

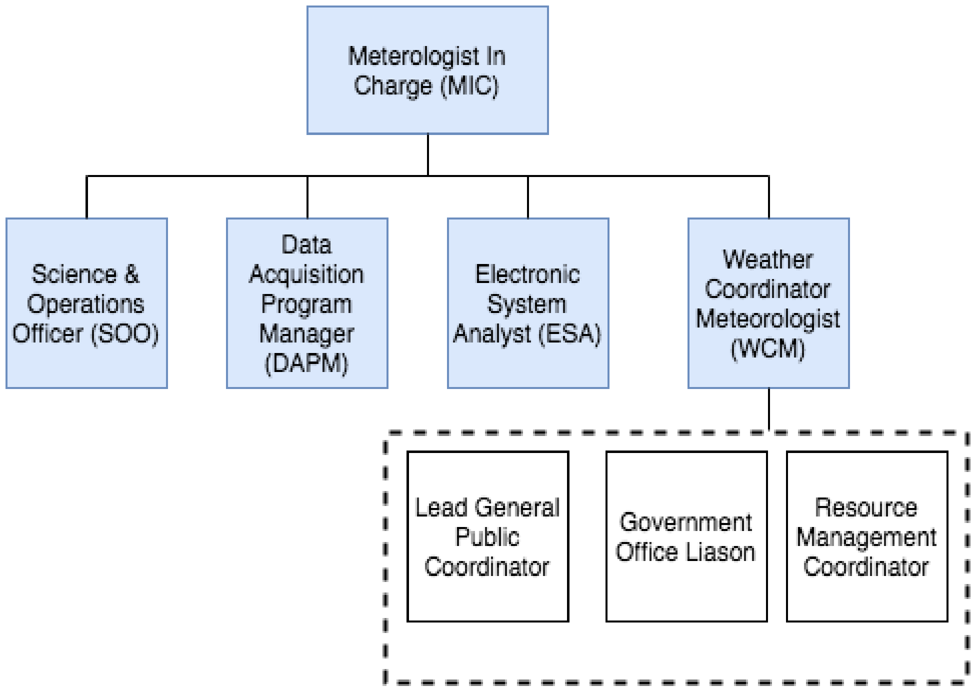

Figure 16. NWS Organizational Structure

The organizational structure above proposes the entire meteorological team to be eliminated and be replaced by a team to assist the weather coordinator meteorologist. There are different types of core partner organizations that would need to be guided during a natural disaster event and having a role that focuses on communicating with each kind would help ensure better communication between the NWS and its core partners. Different organizations carry different priorities and organizational languages, so it is necessary to train each coordinator role for their assigned core partner organization type.

Collecting weather forecasts from partner private companies should be given to the MIC. While analysis should be given to the WCM and the new team. Because analysis will require meteorological expertise, the coordinator roles would need to have a meteorological background.

To both avoid organizational backlash and ensure keeping qualified personnel, the current NWS meteorologist team should be retrained to fill the new coordinator roles. Additionally, the new changes should be implemented incrementally. The first phase should start by refocusing the current forecast team to talk to core partners. The second phase may need to include downsizing, because forecasting efforts would be eliminated. The final phase would include official role changes and clear role definitions.

TRADE STUDY

The optimal solution to improving the NWS can be determined through a trade study to conclude on the solution that will best serve the client needs. During the trade study, each alternative solution is evaluated against measures of effectiveness (MOEs) that serve as a grading scale.

MEASURES OF EFFECTIVENESS

As demonstrated by the figure below, the MOEs aim to measure the effectiveness of each proposed solution based on two categories: the level of effectiveness towards the improvement of the NWS, and implementation ease. The MOEs aim to quantify the minimum level of effectiveness from each measure expected from both alternatives.

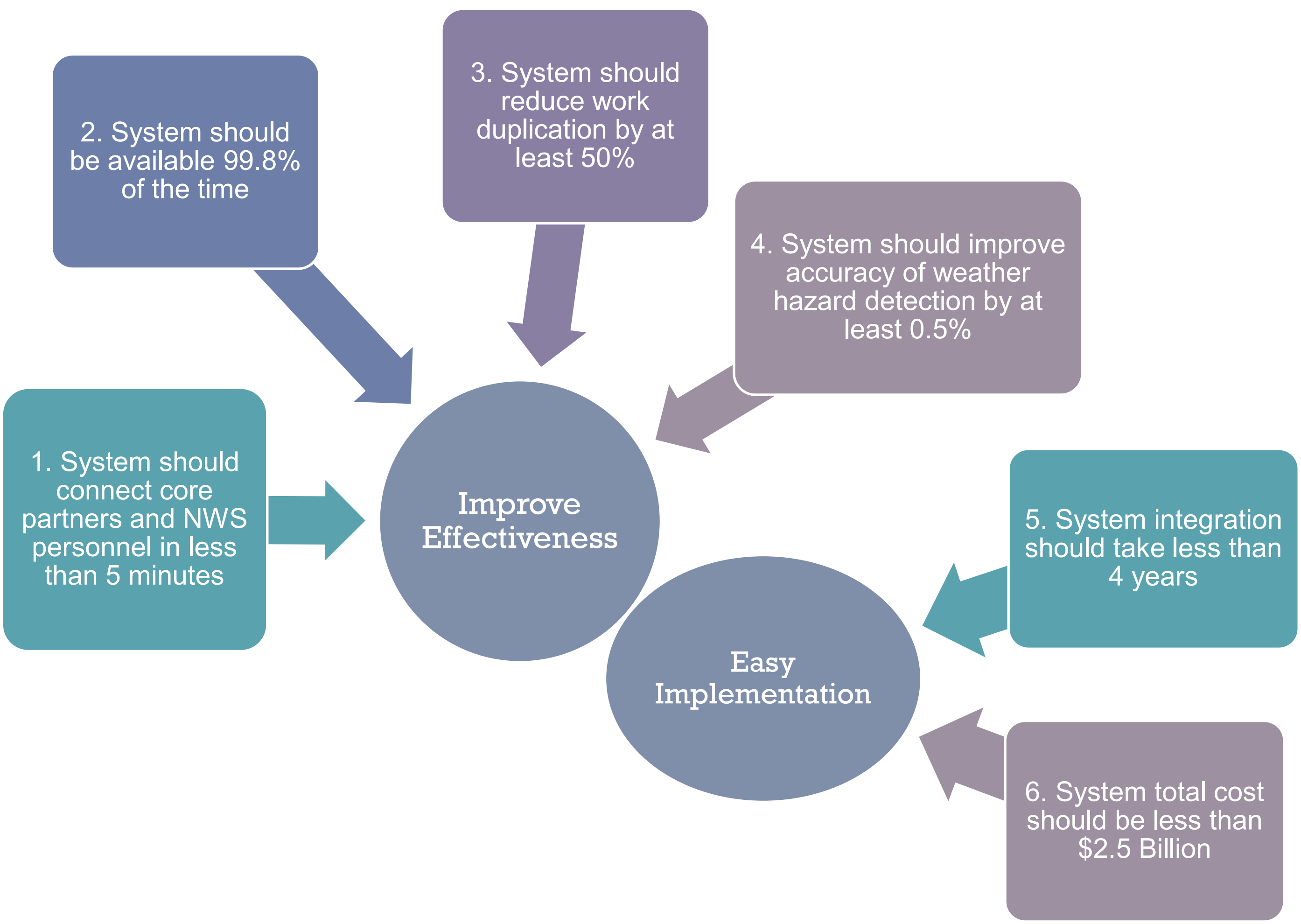

Figure 17. Measures of Effectiveness

By conducting a trade-off analysis between the two alternative solutions based on the defined MOEs, the optimal solution can be identified. As the two alternatives are measured against the MOEs, a point system was devised to aid in the comparison between alternative solutions. As previously stated, the MOEs set a minimum level of effectiveness expected from both alternative solutions. For every factor for which an alternative solution is expected to exceed the minimum level of effectiveness, a point is accredited. The highest scoring solution will be considered the optimal solution.

Alternative 1		Alternative 2	
Chat feature allows communication in 3 minutes on average (include typing time)	+ 2	Phone communication allows instant communication	+ 5
Collaboration / Communication tool expects 99.999% availability	+ 2	Phone system availability is estimated at 99.99%	+ 1
Collaboration tool expects to reduce duplicated work by 60%	+ 1	Organizational structure expects to reduce duplicated work by 70%	+ 2
Collaboration with meteorological community has the potential to increase accuracy by .5%	+ 0	Private companies are comparatively more accurate by 0.5%	+ 0
System development & integration estimated within 2 years	+ 2	Organizational restructuring expected to be completed within 3 years	+ 1
System cost of development and personnel training estimated at 1.5 Billion	+ 1	Organizational retraining could be funded by money saved during downsizing	+ 2.5
	Score 8		**Score 11.5**

As demonstrated by the figure above, alternative 2 is the optimal solution. Alternative 2 recommends that the NWS WFO organization be restructured towards a more effective and efficient system. Restructuring the organization is expected to more effectively increase efficiency and improve communication between NWS personnel and core partners. However, introducing a new communication or collaboration after restructuring the NWS WFO organization would still be possible. Therefore, the detailed designs for the restructuring of the NWS WFO organization should consider an architecture that facilitates the incorporation of a communication or collaboration tool in the future.

The following system views demonstrate a supporting infrastructure for the operational activities expected from the rearchitected NWS WFO organization. These system views aim to follow a similar layout as the organizational structure to better integrate with the organization. The system interface diagram below follows the same system boundaries that were defined by the operational views. The diagrams that follows further details the information exchanged between those interfaces:

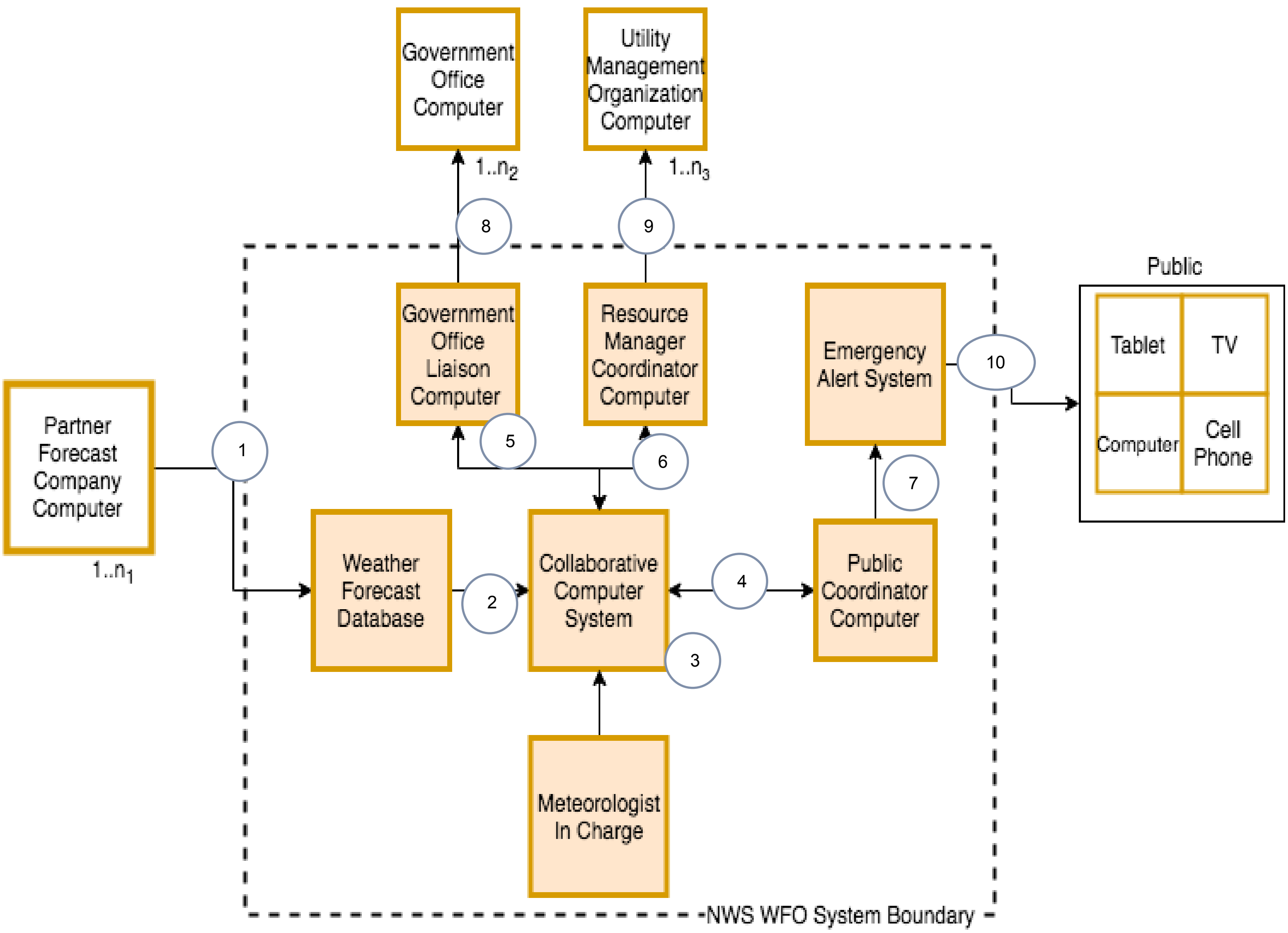

Figure 18. NWS SV-1

Interface	System 1	System 2	Description
1	Partner Weather Forecast Company Computer	Weather Forecast Database	Weather Forecast for WFO counties
2	Weather Forecast Database	Collaborative Computer System	Searchable Weather forecasts
3	Meteorologist in Charge Comp	Collaborative Computer System	Task descriptions/assignments
4	Collaborative Computer System	Public Coordinator Computer	Weather hazard information
5	Gov. Office liaison Computer	Collaborative Computer System	Weather hazard information
6	Resource Manager Coordinator Computer	Collaborative Computer System	Weather hazard information
7	Public Coordinator Computer	Emergency Alert System	Alert Message
8	Gov. Office liaison Computer	Gov. Office Computer	Alert message & Guidance
9	Resource Manager Coordinator Computer	Utility Management Org. Computer	Alert message & Guidance
10	Emergency Alert System	Public Devices	Alert Message

Figure 18. NWS SV-2

	Partner Weather Forecast Co. Comp	Weather Forecast DB	MIC Comp.	Collab. Comp. System	Gov. Office Liaison Comp.	Resource Manager Coordinator Comp.	Public Coordinator Comp.	Emergency Alert System	Gov. Office Comp.	Utility Mgmt Org. Comp.	Public Devices
Partner Weather Forecast Co. Comp		X									
Weather Forecast DB	X			X							
MIC Comp.				X							
Collab. Comp. System		X	X		X	X	X				
Gov. Office Liaison Comp.				X					X		
Resource Manager Coordinator Comp				X						X	
Public Coordinator Comp.				X				X			
Emergency Alert System							X				X
Gov. Office Comp.					X						
Utility Mgmt Org. Comp..						X					
Public Devices								X			

Figure 18. NWS SV-3

In the system functionality diagram below describes the system functionality that is expected to perform the operational activities. The following figure further demonstrates the specific system functionalities that contribute to each operational activity.

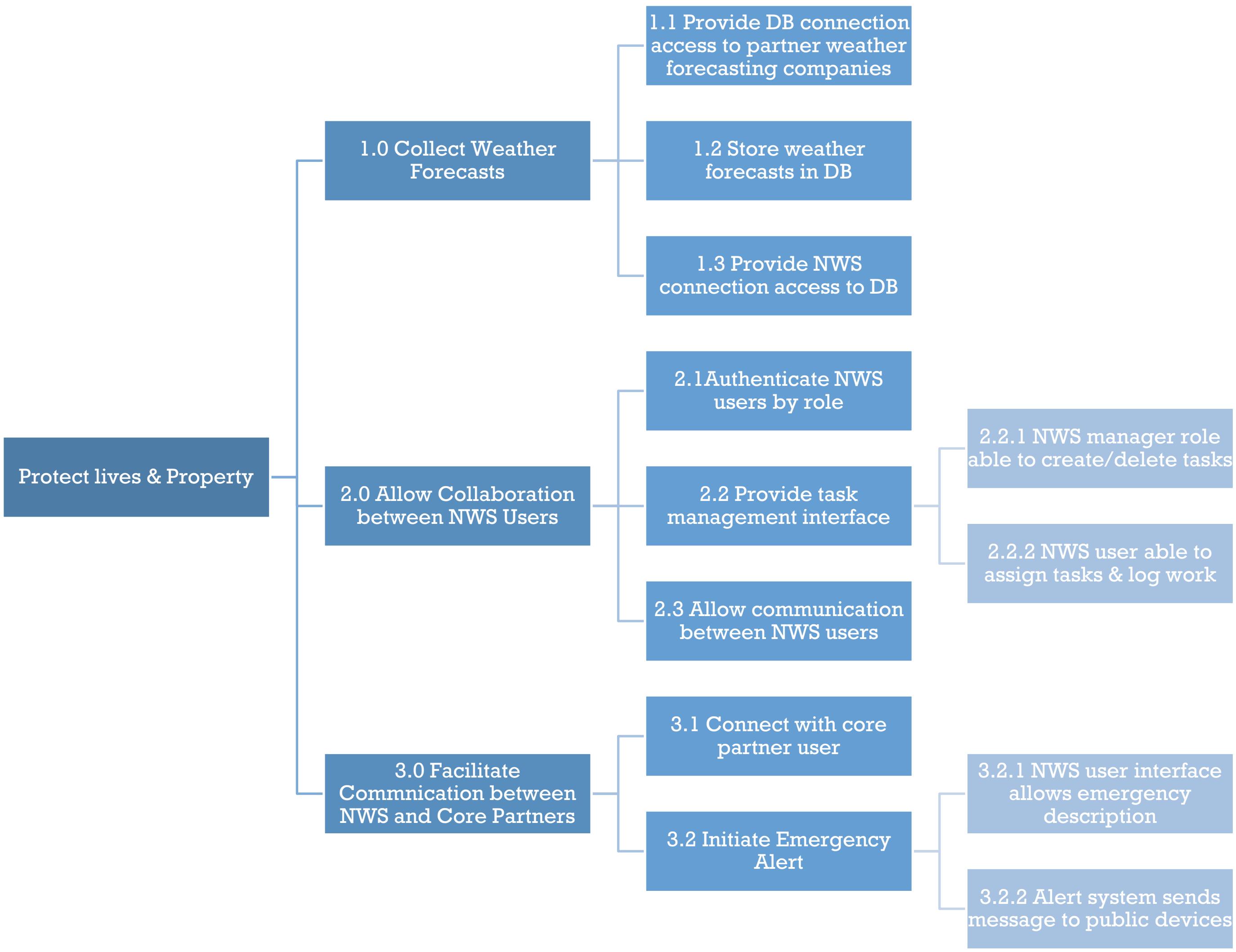

Figure 19. NWS SV-5

RISK ANALYSIS

The following risk portfolio charts summarizes the identified risks and mitigation strategies.

	Marginal	Minor	Moderate	Major	Severe
Almost Certain			D		
Likely				B	A
Possible					E
Unlikely					
Rare			C		

Figure 20. Risk portfolio summary before mitigations

Risk	*Type*	*Description*	*Assessment*	*Mitigation*
A	Cyber Attacks	Hackers could harm the operations with corrupt data or data leaks	Likely event with Severe impact	Database Encryption, network firewalls, and awareness to phishing scams
B	Natural Disaster	Violent Weather can bring the system down	Likely event with High Impact	Maintain redundant alert and communication systems
C	Inaccurate Alerts	Generating false or inaccurate alerts could lower customer support	Rare event with moderate impact	Communicate confidence levels with generate forecasts
D	Organizational Backlash	Current NWS personnel pushback on proposed changes	Almost certain event with moderate impact	Incremental implementation of solution
E	Partner Cooperation	Private weather forecasts do not provide weather forecasts	Possible event that could be severe	Introduce government policy to require cooperation in exchange for COOP data

Figure 21. Risk description table

Mitigations strategies intend to either lower the impact or the likely hood of an event. The risk summary chart below demonstrates the expected effect that the mitigation strategies will have on the identified risks.

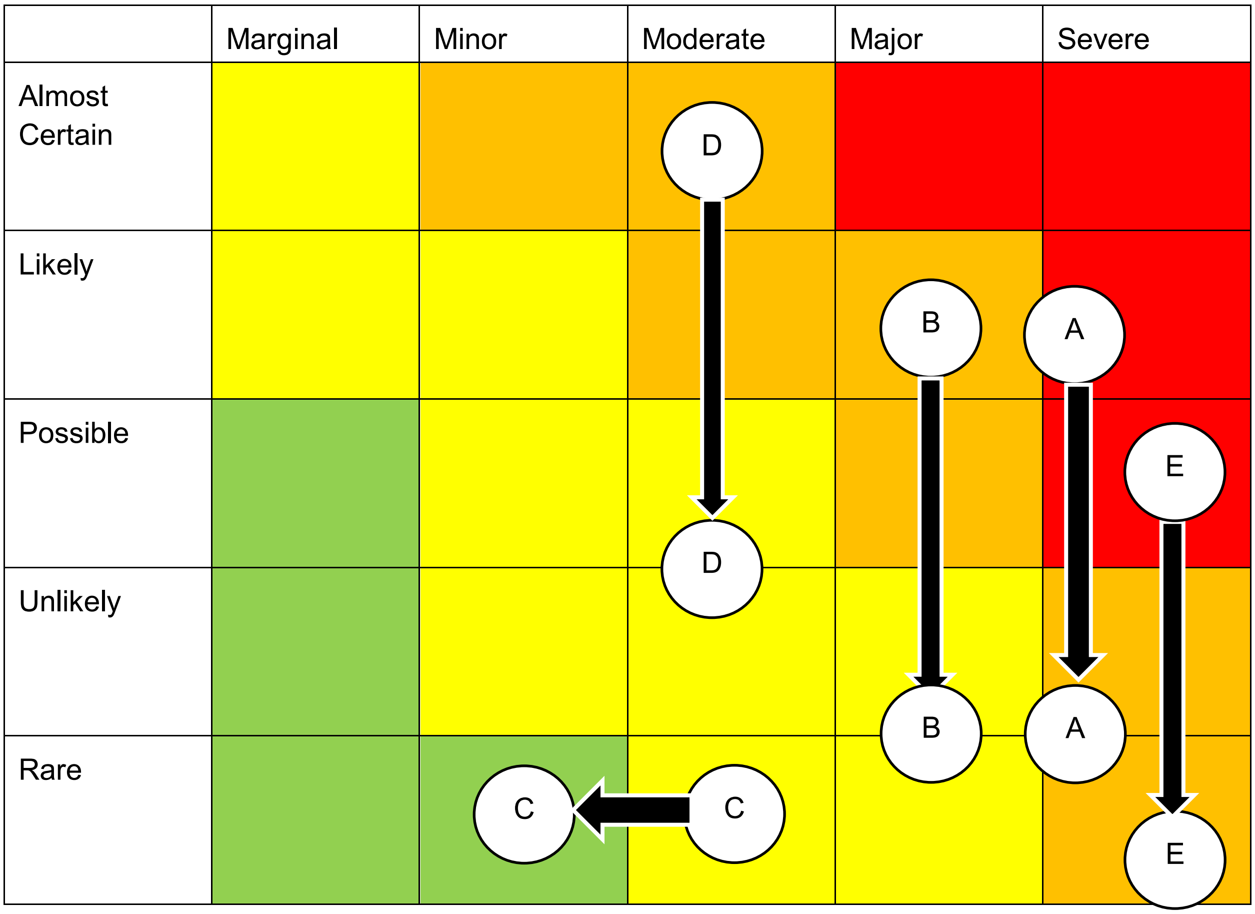

Figure 22. Risk portfolio summary after mitigations

ETHICAL REVIEW

The efforts to improving the NWS is guided by the mission to protect lives against weather related events. However, some ethical concerns arise over the practices that the NWS is being encouraged to perform. This section will address the ethical concerns that exist with the expected operational activities and analyze them according to an appropriate ethical lens.

The restructured NWS is suggested to eliminate the weather forecasting practices, which leads the general public to rely on private weather forecasting companies for weather forecasts. However, the tax payers are funding a subset of the weather observational practices used by private weather forecasting companies. An ethical concern arises when considering the fact that the general public will no longer have a publicly available weather forecast source but are still expected to fund weather observational practices. Under the rights lens, the public can be seen as the client that has a right to the generated weather forecasts that the NWS produces. However, the private companies are adding value to those generated forecasts by investing their own time and effort. For that reason, the private companies are not unethically profiting off of the NWS generated weather forecasts. In fact, the weather dependent companies have a right to profit from the added value that they are providing. For example, the weather channel is a subscription paid television service that is heavily dependent on the generated forecasts produced by the NWS, but the television service provides additional entertainment that goes beyond simply presenting the weather forecasts. Actually, the weather channel website makes the generated weather forecasts publicly available and only profit from the added value they provide. Additionally, tax dollars are primarily funding the efforts of the NWS aimed towards analyzing weather hazards and initiating emergency alerts. Therefore, the U.S taxpayer is receiving a reliable emergency alert service that protects them from weather events for their tax dollars. Meanwhile, the NWS could continue to fulfill its mission to enhance the U.S economy without unethically forcing the public to pay for the generated weather forecasts that the taxpayers are funding.

RECOMMENDATIONS

The U.S government is recommended to rearchitect the NWS to serve the increased need for weather protection. The structure proposed in this paper will be best implemented as a slow integration over 3 phases.

Phase 1

The initial phase should focus on retraining the meteorologist team members to interact with core partners. This phase aims to ease the meteorologist team from focusing on forecasting efforts to acting as designated core partner coordinators. The meteorological team's expertise will allow them to better guide and support core partners. Training should focus on developing communication skills and learning standard coordination procedures.

Phase 2

This phase should set up partnerships with private weather forecast companies and incorporate commercial weather forecasts. Downsizing may be necessary, as the forecasting efforts should also be eliminated during this phase.

Phase 3

Official Role & Team Changes

A portion of the NWS budget is usually reserved for science & technology integration and a portion of that budget may be used to fund the initial efforts of implementing this solution. For the next fiscal year budget proposal, the budget should include specific estimates needed to fund the new role development, training and tool development contract. A budget estimation should be performed to better plan the financial support that will be needed to implement the recommended solutions

Additionally, the proposed solution was developed with the intention to facilitate the integration of a collaboration and communication tool. The U.S government is recommended to invest in developing a new collaboration and communication tool that will facilitate the rearchitected NWS achieve its goals. The tool could be developed under a private company contract and integrated in the future.

Improving the NWS will benefit many and it is in the U.S government’s best interest to invest in the solution proposed in this paper.

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