The Application of Systems and Software Engineering Process Models for Development on Small to Moderate-Sized ITS Projects: WeatherShare and the Redding Responder Projects

National Rural ITS Conference 2006
Big Sky Montana
Tuesday, August 15th, 2006
2:45 pm
Session G2: Using Existing Technology in New Ways

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MONTANA STATE UNIVERSITY | College of ENGINEERING

Mountains & Minds

Related Sessions:

The Redding Responder Project: Mobile Data Communication Challenges in Remote Rural Areas
Session A4: Innovative Communication Solutions
Monday, August 14th, 9:45 am

The Redding Responder Project: Computing and Communication in the Middle of No-Where
Session H2: Innovative Data Collection and Sharing
Wednesday, August 16th, 8:30 am

The WeatherShare Project: Aggregation and Dissemination of Weather Information for Public Safety
Session B4: Innovative Data Collection and Sharing
Monday, August 14th, 12:30 pm

Abstract:

In cooperation with the California Department of Transportation, Montana State University's Western Transportation Institute has developed the WeatherShare and Redding Responder "proof-of-concept" systems by applying Systems Engineering and Software Engineering techniques.

These techniques, often associated with large-scale, multi-million dollar projects, can be applied successfully to smaller projects resulting in systems that best meet user needs in a cost-effective and technically sound and feasible manner.

This presentation will provide a summary of processes followed in the WeatherShare and Redding Responder projects and the relationship of these processes to the Caltrans Stages of Research Deployment, as well as resulting design decisions.

Systems Engineering

Systems engineering is an interdisciplinary approach and means for enabling the realization and deployment of successful systems. It 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: operations, environment, design, development, manufacturing, deployment, cost & schedule, performance, training, maintenance, test, and disposal.

Systems Engineering integrates all of the engineering disciplines and specialty groups, or ilities, into a unified, team effort, forming a structured development process that proceeds from concept to production to operation and, in some cases, through to termination and disposal.

Source: Wikipedia - http://en.wikipedia.org/wiki/Systems_Engineer

Systems Engineering

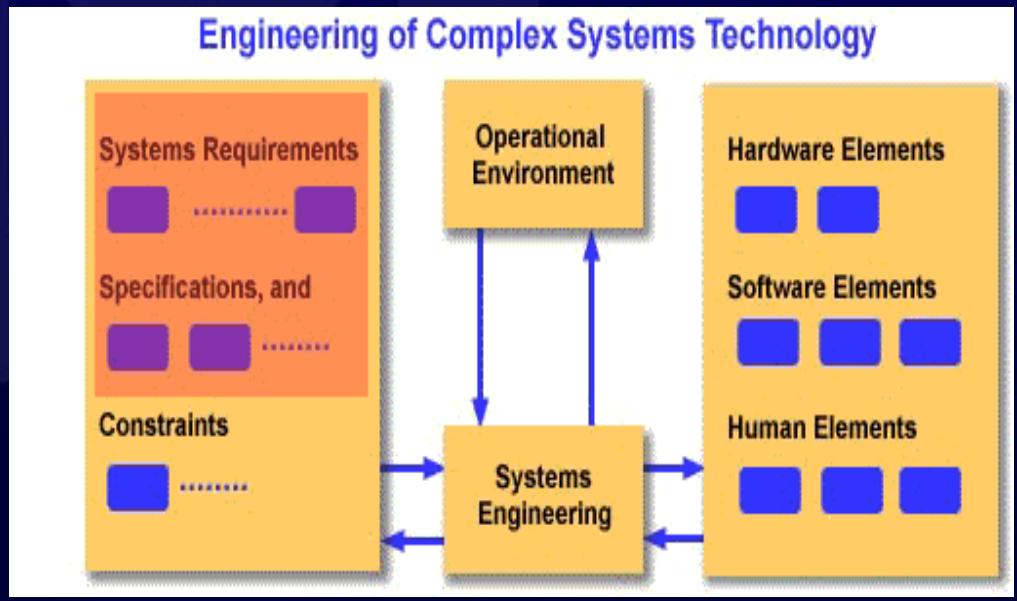
Using a systems engineering approach, large and/or highly complex engineering projects are often decomposed into stages and then managed throughout the product or system lifecycle. This process of managing the system's lifecycle resembles a series of interconnected engineering projects, each executed in sequence and drawing upon the results of preceding or contemporaneous projects, until the desired end result is achieved.

Source: Wikipedia - http://en.wikipedia.org/wiki/Systems_Engineer

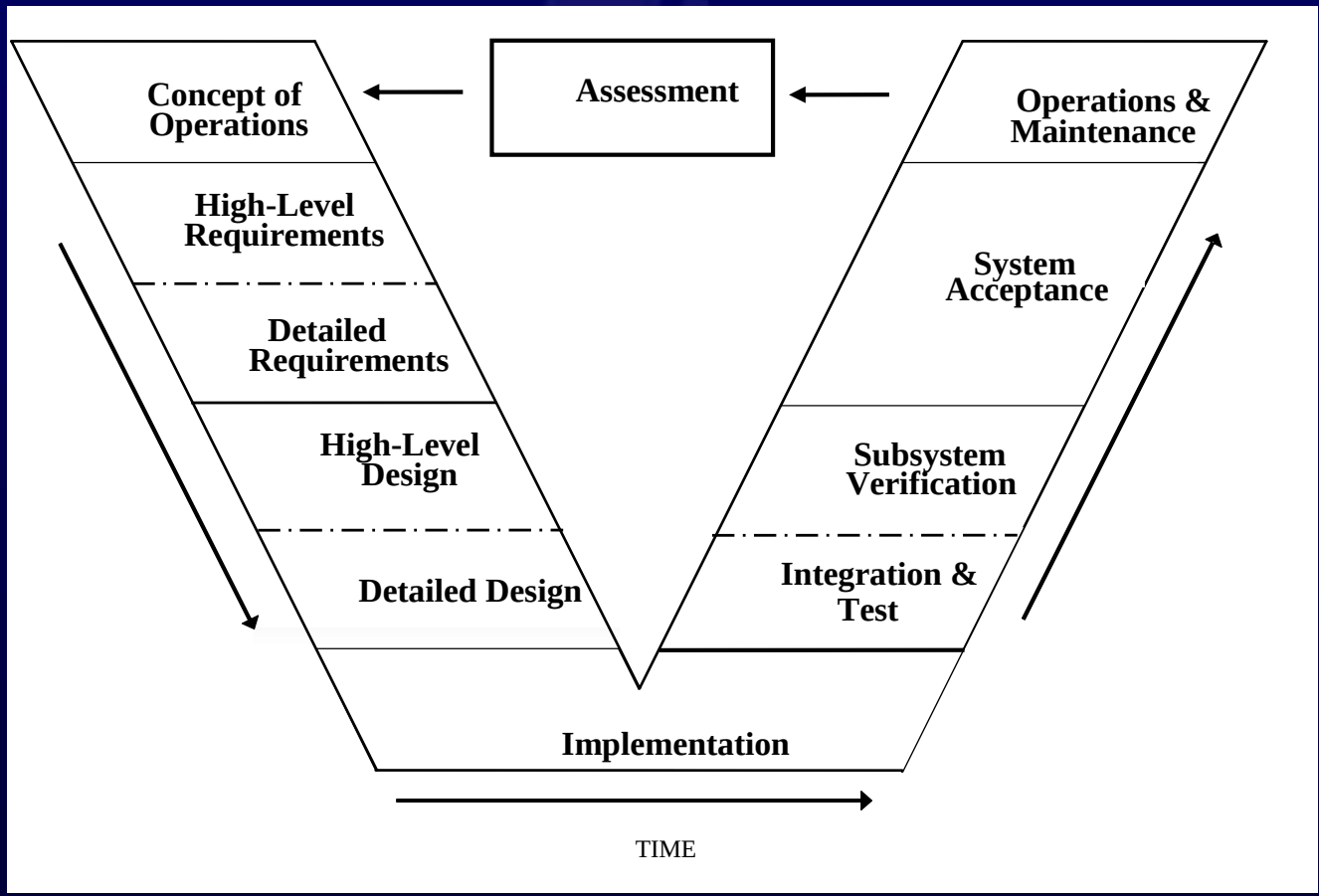
What is Systems Engineering?

A set of management tools/techniques to ensure that systems are built:

- to work,
- to satisfy the customer needs, and
- to meet acceptable cost and schedule constraints



"V" Model


Concept of Operations
High-Level Requirements
Detailed Requirements
High-Level Design
Detailed Design
Implementation
Assessment
Operations & Maintenance
System Acceptance
Subsystem Verification
Integration & Test
TIME

Challenges:

- Can “Systems Engineering” be applied to “small” projects?
- Should you follow a strict or loose interpretation of the process models?

Application to Two Caltrans Research Projects

- WeatherShare
- Responder

WeatherShare Background

- Aggregation and Dissemination Server for Weather Data.

- Covers a 20-county, Northern Calif. region with >2,000 miles of highways.
- 11 Caltrans RWIS stations and >700* other weather stations
- A component of the Redding Incident Mgmt. Enhancement (RIME) program.

- Phase I Stakeholders include:

Caltrans

SHASCOM-911
SHASTA COUNTY, CALIF.

Nor-Cal EMS

CALIFORNIA DEPARTMENT of FORESTRY and FIRE PROTECTION
C D F
FORESTRY
FIRE

Goals of WeatherShare

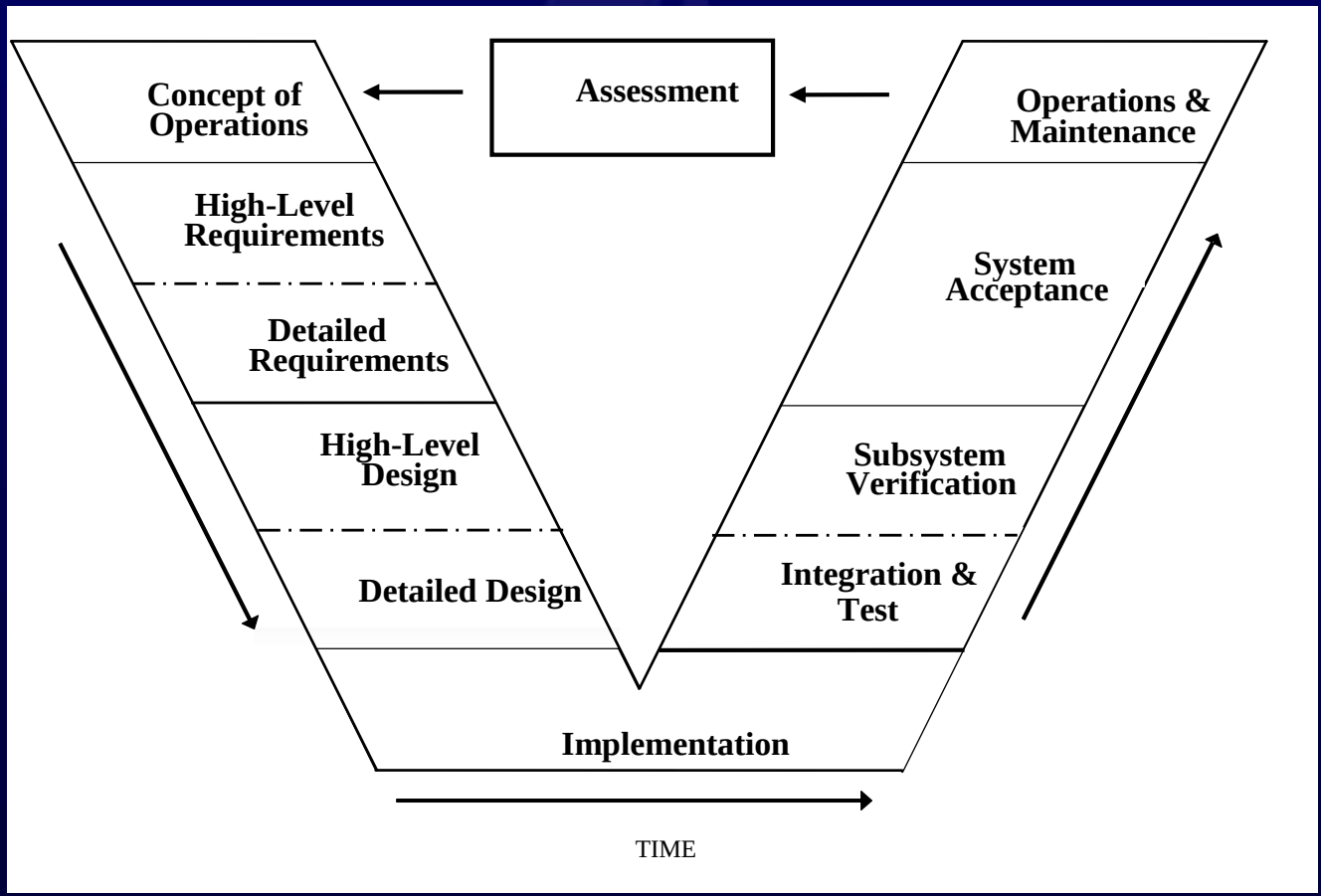
- To streamline and integrate currently available road weather data from Calif. RWIS sites, Calif. Dept. of Water Resources (CDWR) stations, and other sources available into a single source, where relevant information is accessible by incident responders and the traveling public.

- This system will allow users to make informed and efficient assessment of current road weather conditions for: incident management, highway maintenance, emergency medical services (EMS), traveler information, and possibly homeland security applications.

Systems Engineering Process

- Phased approach
  - Phase I: Prototype system
  - Phase II: Full system
- Follow the V model on a small scale

"V" Model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What is the Concept of Operations?

- A document that defines the environment in which the system is to operate.
- Environment includes
  - Relationship between the system and the users
  - Physical environment
  - Expectations (performance and life).

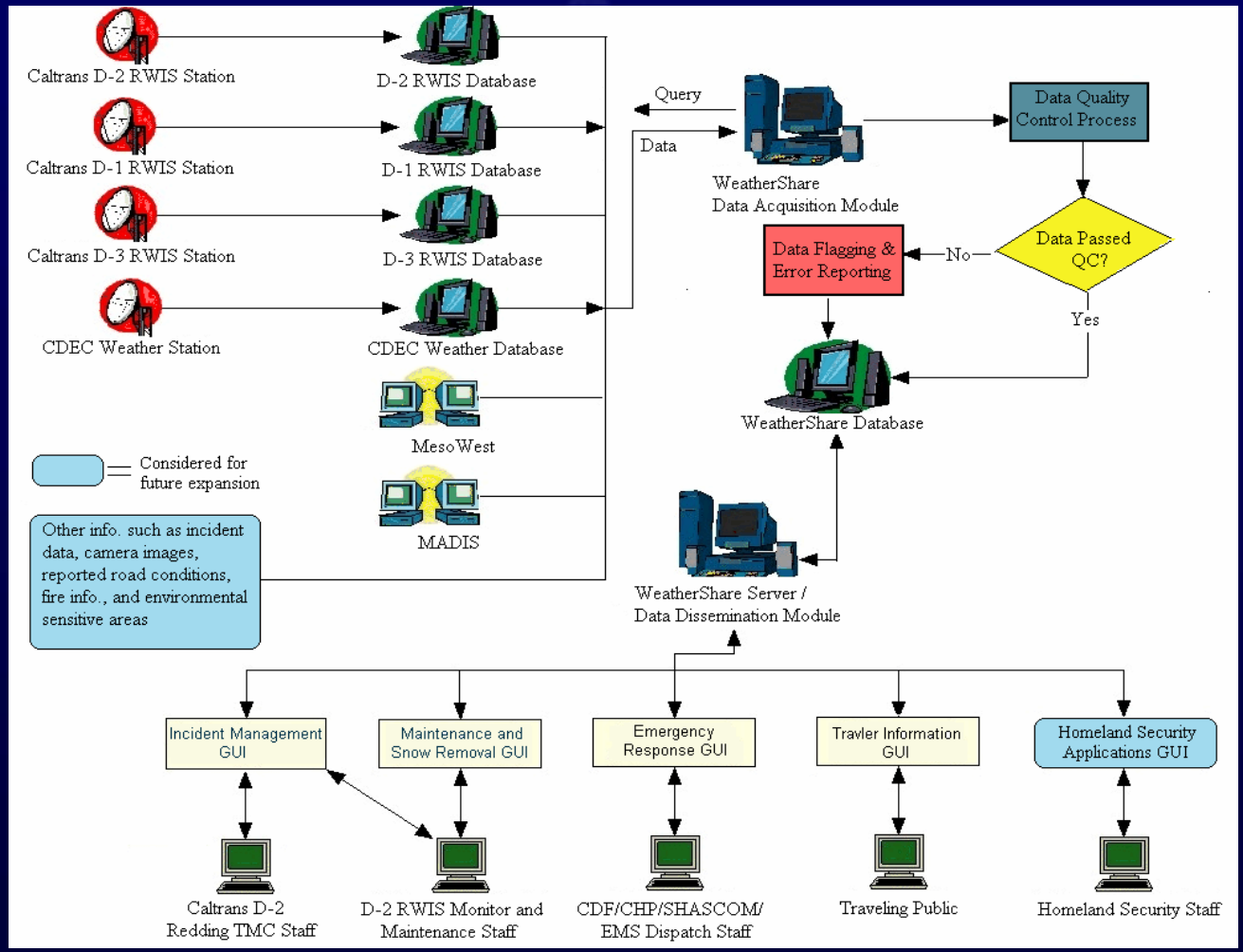
Outline of ConOps

- Scope
- Referenced Documents
- Current system or situation
- Justification for and nature of changes
- Concept for a new system
- Operational scenarios
- Summary of impacts
- Analysis of the proposed system

IEEE Standard 1362-1998

http://standards.ieee.org/reading/ieee/std_public/description/se/1362-1998_desc.html

WeatherShare "Concept for New System"



Data Sources, Update Frequency & Sensor Readings

- CDEC(420 stations): every 15 minutes

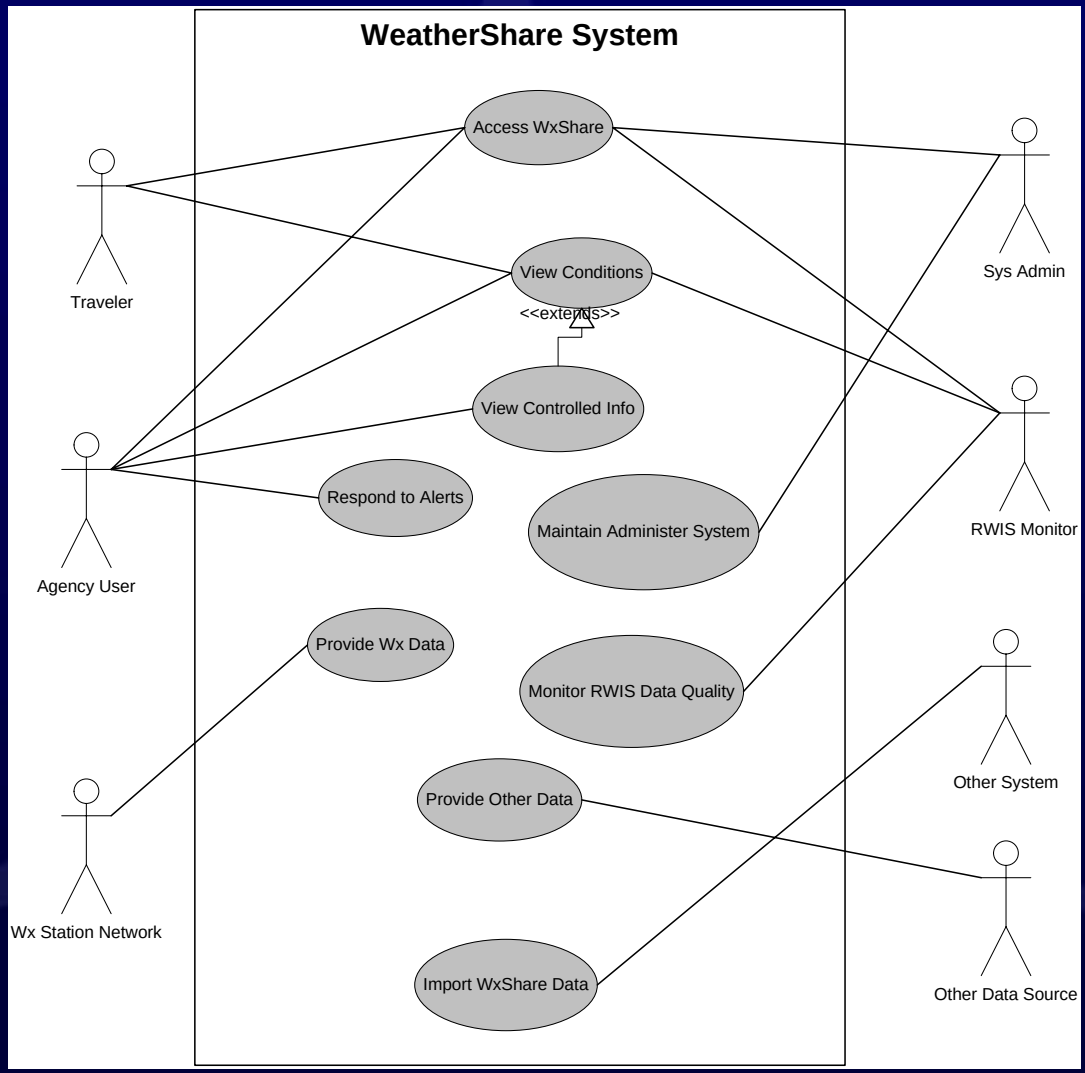
  Air Temperature, Relative Humidity, Avg Wind Speed, Avg Wind Direction, Max Wind Gust Speed, Max Wind Gust Dir, Atmospheric Pressure, Solar Radiation, Fuel Moisture, Fuel Temperature, Precipitation, Reservoir Elevation, River State, water temperature.
- MADIS(39 stations): every 30 minutes

  Air Temperature, Relative Humidity, Avg Wind Speed, Avg Wind Direction, Max Wind Gust Speed, Max Wind Gust Dir, Dewpoint Temp, Atmospheric Pressure, Fuel Moisture, Fuel Temperature, Precipitation Rate, Precipitation in 24Hours.
- MesoWest(229 stations): every 15 minutes

  Air Temperature, Relative Humidity, Avg Wind Speed,Avg Wind Direction,Max Wind Gust Speed, Atmospheric Pressure, Solar Radiation.
- District II RWIS(11 stations): every 30 minutes

  Air Temperature, Dewpoint Temp, Max Temp, Min Temp, Avg Wind Speed, Max Wind Gust Speed, Avg Wind Direction, Max Wind Gust Dir, Relative Humidity, Precipitation Intensity, Precipitation Rate, Accumulate Precipitation, Visibility.

Use Case Diagram Used in Conops, Requirements Analysis and Design



System Requirements

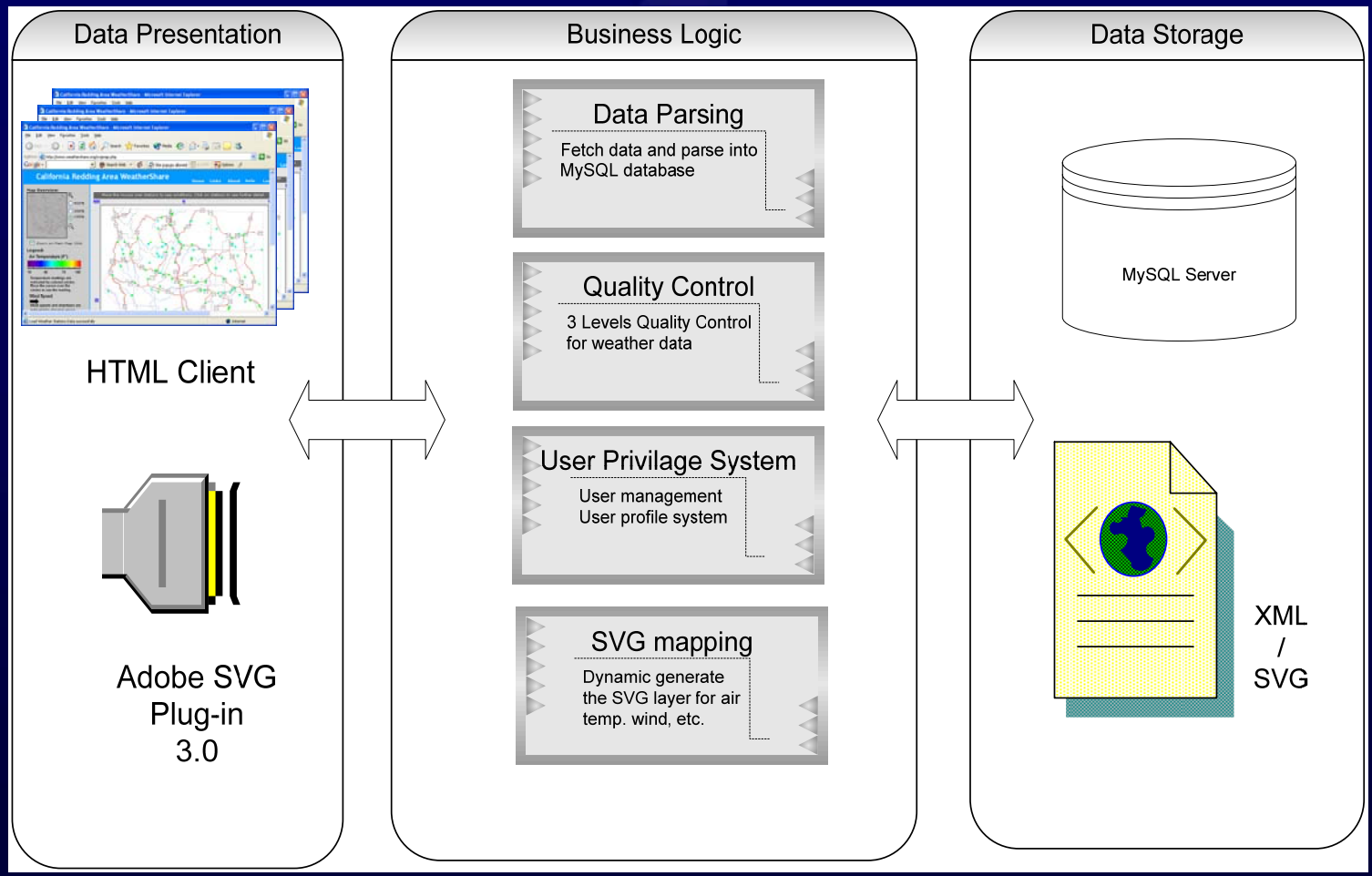
IEEE Recommended Practice for Software Requirements Specifications (IEEE Std 830-1998)

System Requirements and Design

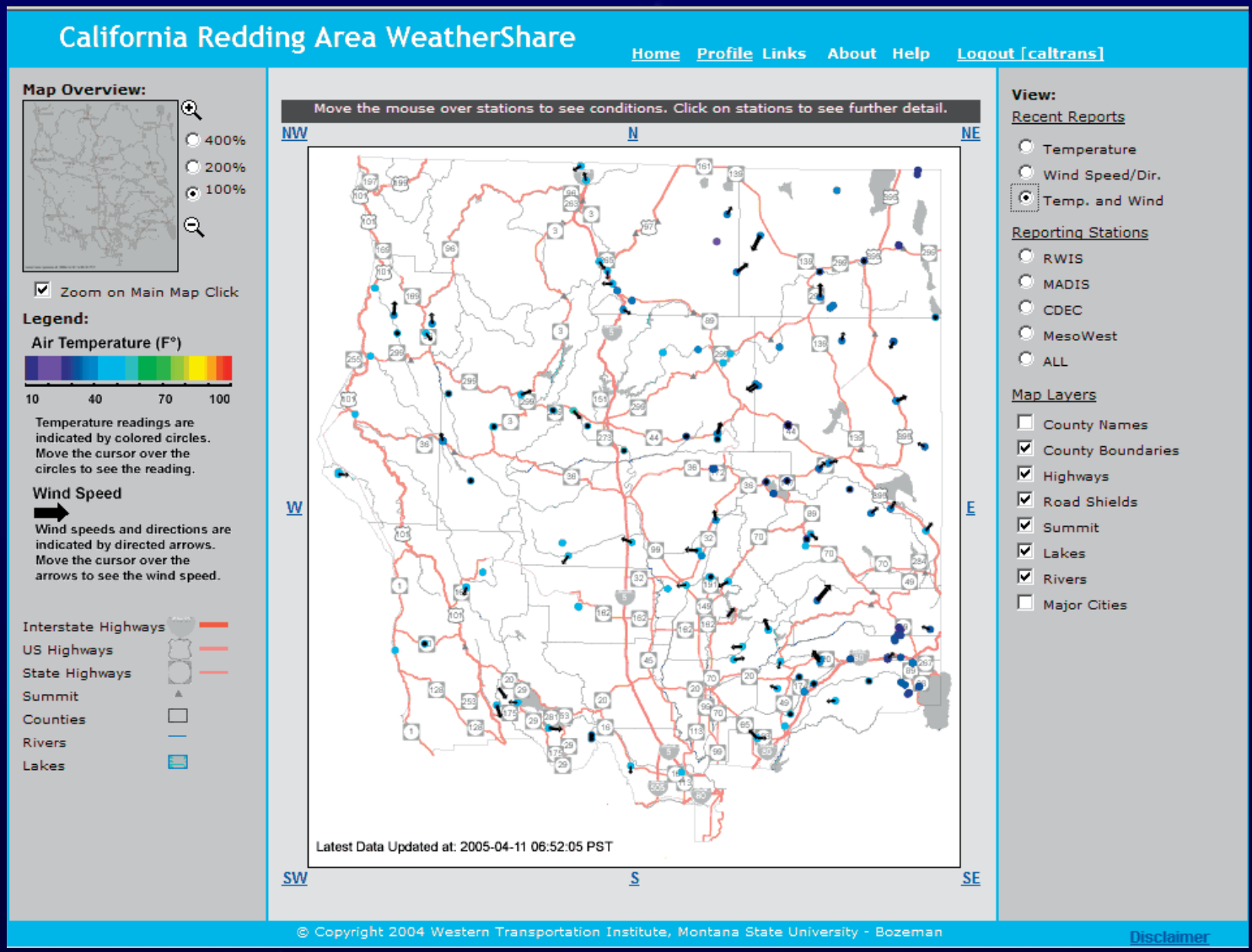
Follow and Iterative Process in defining requirements and design through:

- Identification of stakeholder needs
- Literature review
- Conducting online surveys
- Elicitation and formulation of requirements
- Identification and evaluation of alternatives
- Design, development, implementation and maintenance of systems

Multi-tier System Architecture High Level Design



Resulting Prototype (#2): www.weathershare.org



Preliminary to WeatherShare Phase 2

We have:

- A working, proof-of-concept system.
- Detailed concept of operations, requirements.

The “Responder” Problem

Question:

“There’s a rock in the road. How big is it?”

Problem:

How do you convey this information to someone who isn’t there, looking at the rock alongside you?

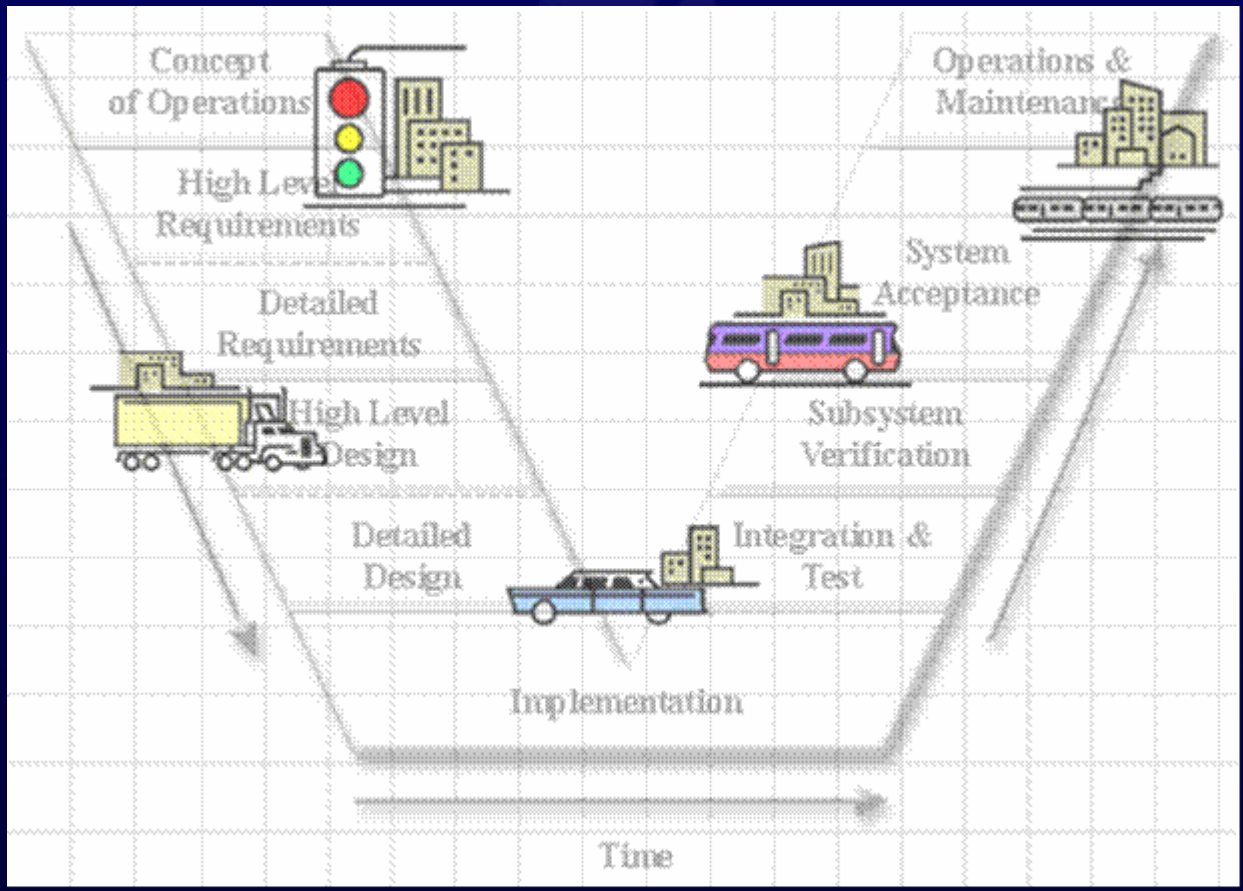
(Technology) Solution: Build or Buy?

- Determine District 2's needs in regard to this problem.
- Conduct research of prospective technologies in an objective manner.
- Apply research to integrate technologies into a proof-of-concept system that addresses District 2's needs.

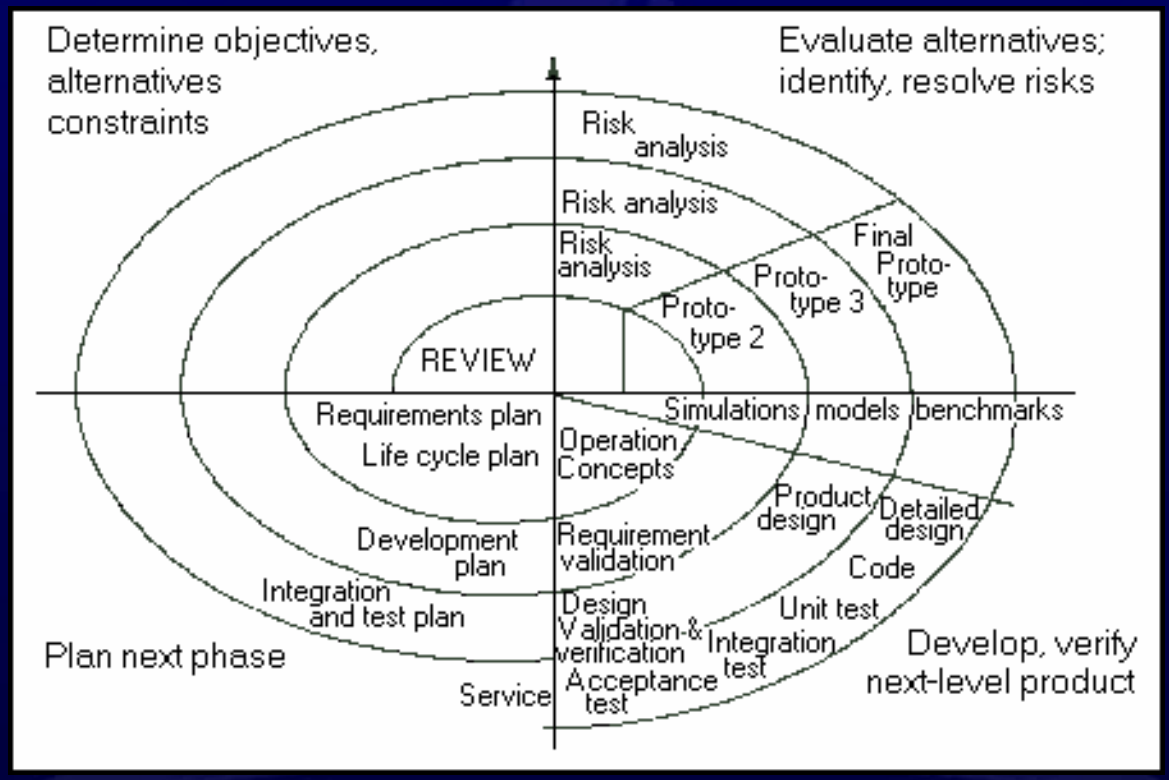
Process = A Combination / Hybrid

- Systems Engineering Process – “V” Model
- Spiral / Iterative Process Model
- Caltrans Stages of Research Deployment

Process
Systems Engineering Approach



Process
Spiral / Iterative Process Model



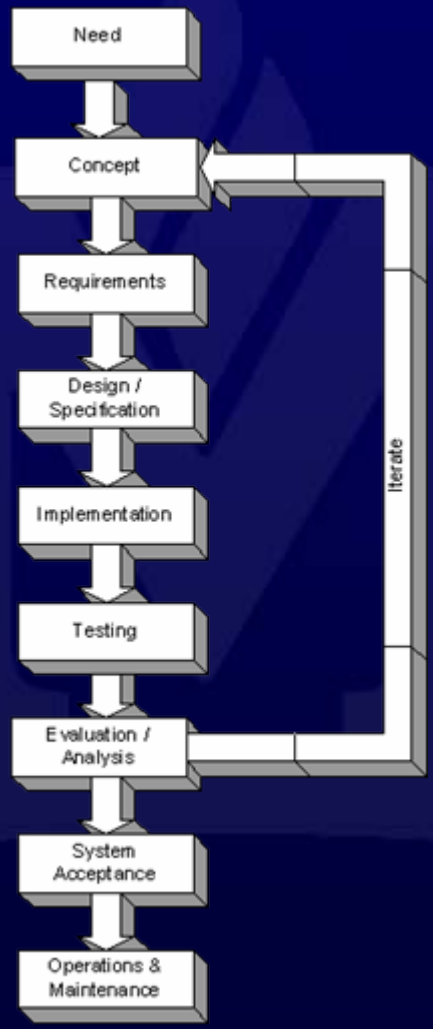
Source: A Spiral Model of Software Development and Enhancement, Barry W. Boehm, TRW Defense Systems Group, May 1988, IEEE Computer

Process

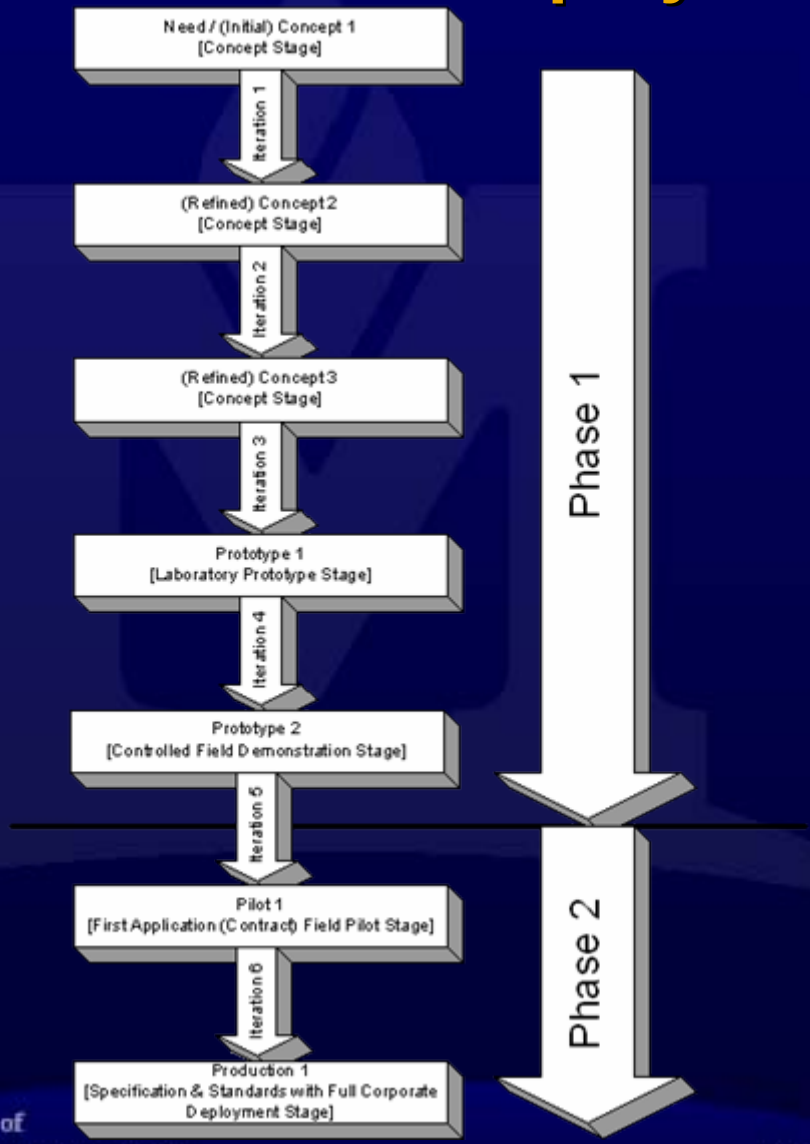
Caltrans Stages of Research Deployment

- Concept Stage
- Laboratory Prototype Stage
- Controlled Field Demonstration Stage
- First Application (Contract) Field Pilot Stage
- Specification & Standards with Full Corporate Deployment Stage

Resulting Iterative Project Process Model



Correspondence to Caltrans' Stages of Research Deployment



Need / (Initial) Concept 1 [Concept Stage]

Original Concept:

To enhance the collection and delivery of 'real-time' incident information, a study will be conducted to investigate, analyze and make recommendations on an electronic data collection and communications system for Redding District maintenance personnel. The concept is that the maintenance personnel would use the system to provide information to the traffic management center, track and inventory at-scene equipment and materials provided and serve as a record for post incident analysis.

October 2003 Kickoff Meeting

D2 Director:	*"Responder should consider EMS, fire department, and other needs, but at this stage should focus on collecting incident information needed by Caltrans"*
D2 Maintenance Manager:	*"What is the incentive for the at-scene responder to input all the incident information to a device? Time is precious. So maybe the at-scene data collection device should be automated."*
D2 Maintenance Manager:	*"Possible Use: There's a rock in the road. How big is it?"*
D2 ITS Engineer:	*"Build a mobile data terminal for use in rural areas. Incorporate 802.11 for local area communication."* *Communications is KEY in the District 2 area and the most reliable coverage (for external communication) might be the satellite phone system. Cellular phone coverage is neither 24/7 nor available anywhere in the area (due to mountainous geographical characteristics)*
DRI Project Manager:	*"Make it of use in urban areas as well."*
D2 Maintenance Manager:	*"Information should flow both ways between the at-scene personnel and TMC."*
WTI Research Team:	*"A Tablet PC and Digital Camera could be used to incorporate Digital Photos and other data."*
D2 Director:	*"Responder project should have a research component. (What can be learned from the project? What results can be applied elsewhere?)"*

(Refined) Concept 2 [Concept Stage]

Refined Concept:

The Responder System will consist of integrated hardware, software and data communication equipment capable of recording and transmitting incident information from the scene of incidents occurring anywhere (rural or urban) within the RIME region. It would also be capable of receiving information (data) from the outside, including the Redding TMC.

High-Level Requirements

- A system shall be implemented to collect incident information.
- The system shall be used by Caltrans' staff, but shall be of potential for use by EMS, fire and other agencies.
- The system shall be deployed within Caltrans' vehicles in the field.
- The system shall be operational within and in the vicinity of Caltrans' vehicles in the field.
- The system shall be easy to use.
- The system shall automate the collection of incident information.
- The system shall minimize the amount of time required for use.
- The system shall transmit information to the TMC and other outside agencies.
- The system shall receive information from the TMC and other outside sources.
- The system shall have data communications capability in all areas of District 2.
  - The system shall be operable in rural areas including mountainous areas.
  - The system shall be operable in urban areas.

Preliminary Design / Specification

- The system shall use a Tablet PC as a mobile data terminal to collect and record incident information.
- The system shall use a digital camera to collect digital photographs of incidents.
- The system shall use satellite communication to provide data communication capability in mountainous areas.
- The system shall use cellular data communication to provide data communication capability in urban and other areas where cellular communication is available.
- The system shall use IEEE 802.11 –based (Wi-Fi) wireless technology to implement un-tethered use in the proximity of parked Department vehicles in the field.

(Refined) Concept 3 [Concept Stage]

Revised (Final) Concept:

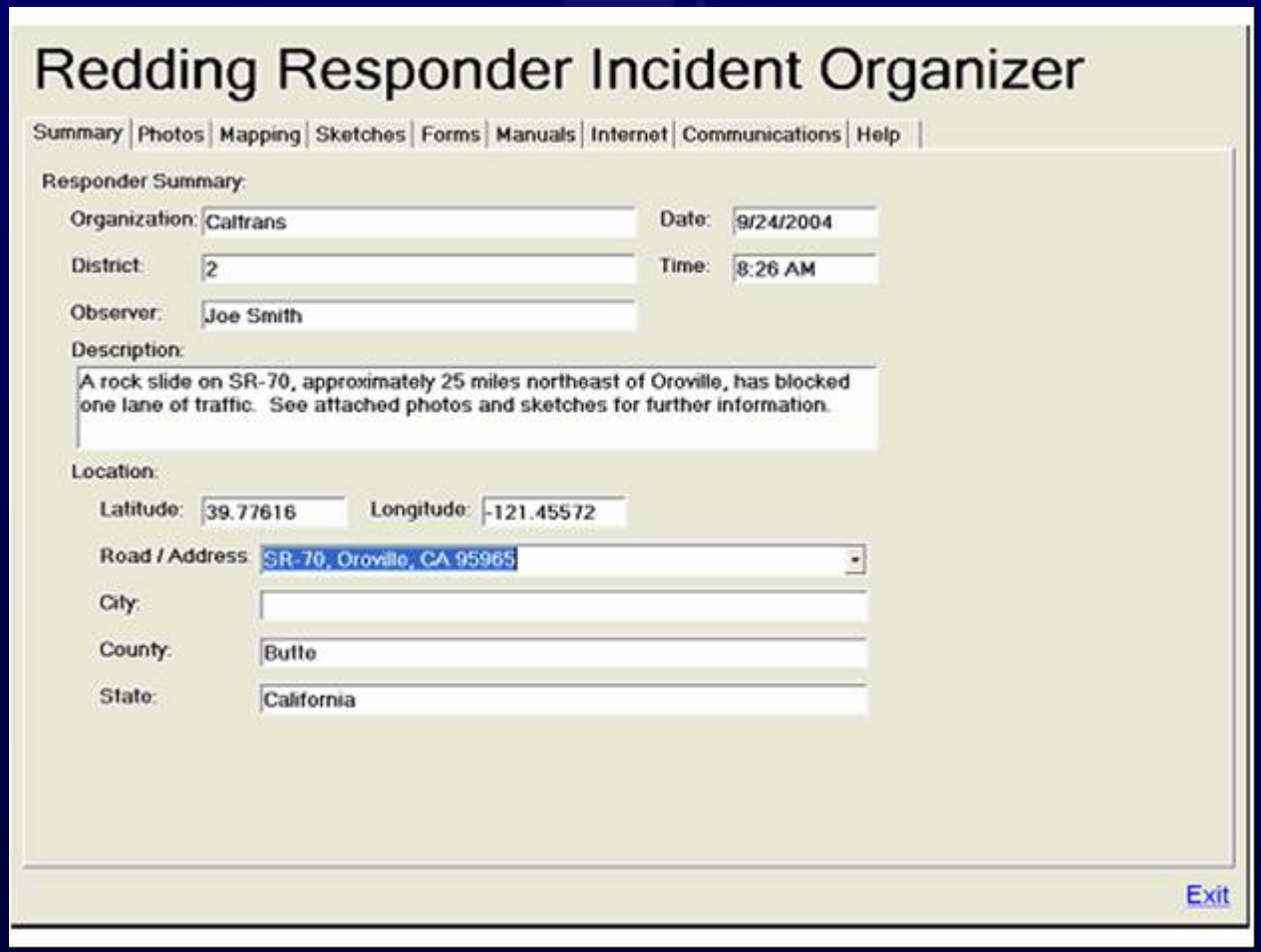
A system integrating hardware, software and communications shall be developed to give responders the ability to download and use pertinent and available electronic data including maps and aerial photographs as well as weather conditions. The system will also allow for the collection and transmission of at-scene information that is difficult to convey via voice communications. Photos can be taken at the scene, associated with data such as time and GPS location, and organized to provide a more complete picture of the scene. Photos can be enhanced with hand-drawn diagrams outlining the situation and plans in much the same way a football coach might outline a formation or play on a chalkboard. Forms can be included and tailored to a situation or by responsibility, facilitating more accurate and timely recording of information as well as future evaluation and analysis.

Prototype 1 [Laboratory Prototype Stage]

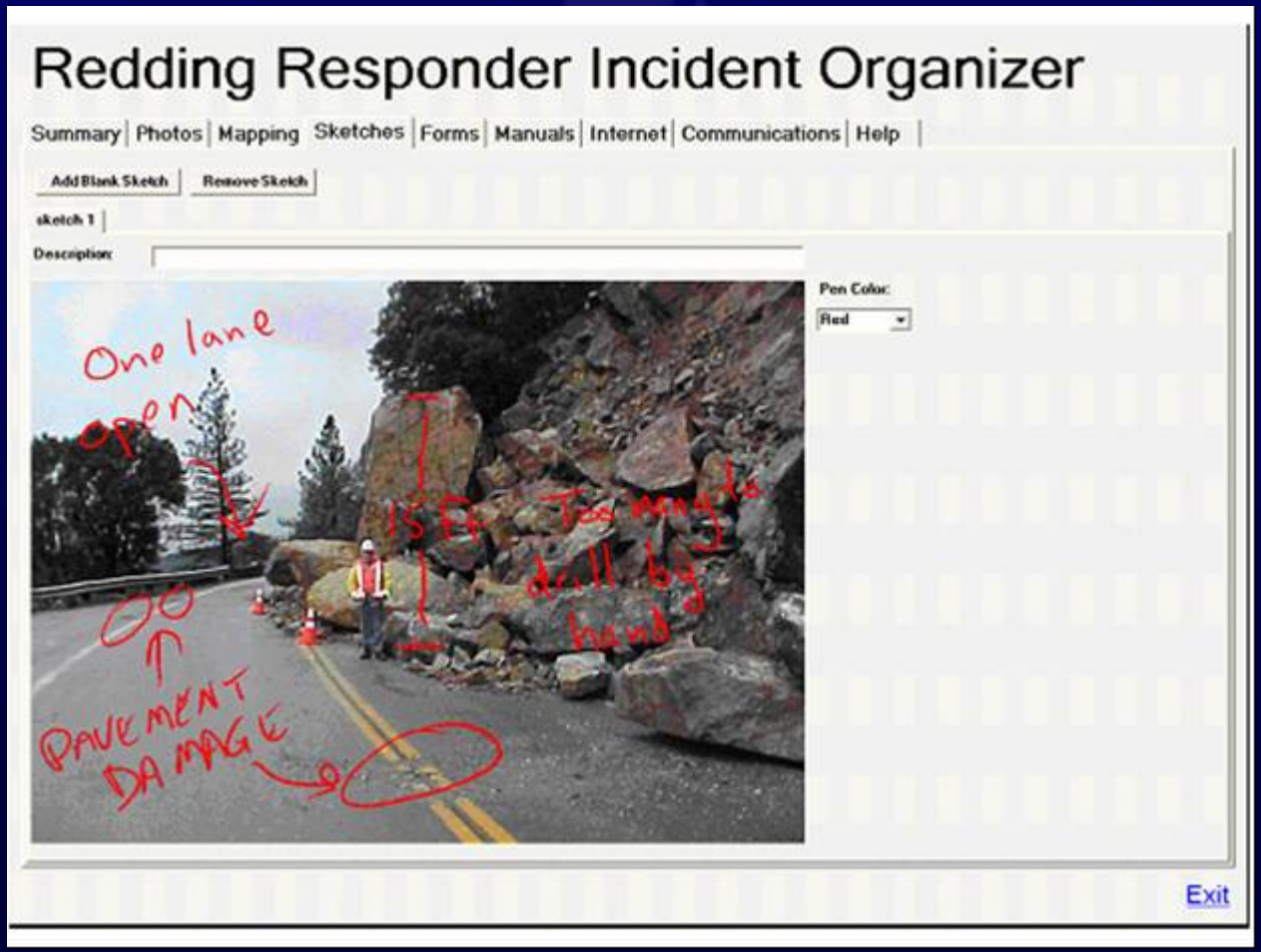
A functional prototype was developed consisting of OTC hardware, software and communication components and services.

Splash Screen

Incident Organizer



Photos and Sketches



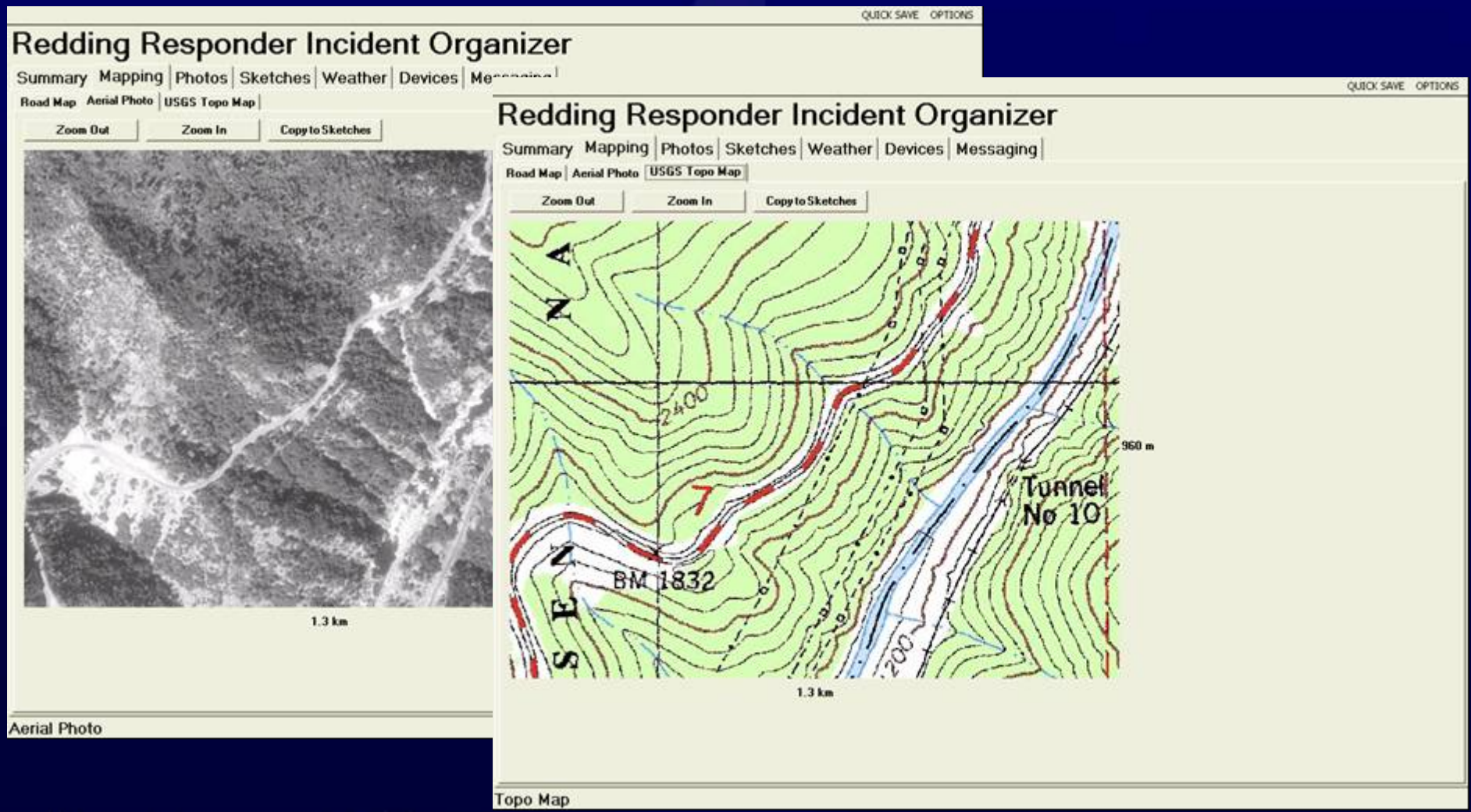
Hardware in the Vehicle

Prototype 2
[Controlled Field Demonstration Stage]

A second functional prototype was developed consisting of OTC hardware, software and communication components and services.

This prototype was fully-functional and field-usable, but not field hardened.

Maps – Preloaded



Weather – “Get Weather”

Hardware

- Wireless capability added to make the system self-contained and portable.
- Tablet PC can be used un-tethered.

The Responder “Briefcase”

Preliminary to Phase 2 Pilot 1 [First Application (Contract) Field Pilot Stage

We have:

- A working, proof-of-concept system.
- Detailed requirements.
- An evaluation of communication, hardware and software alternatives.

Conclusions

The Systems Engineering Process can be followed on small- to mid-sized ITS development projects.

Flexibility and “common sense” judgment are key in applying best practices.

Clearly defined phases and sub-phases are important: prototype, (proof-of-concept), pilot and production.

Acknowledgements

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  - Steve Albert
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  - Sean Campbell
- Caltrans D2
  - Jeff Kiser
  - Ian Turnbull
  - Many Others
- Other Stakeholders
  - Norcal EMS
  - CDF
  - Shascom
  - Others