Project 5: Aerial Video Processing in Support of Disaster Response

SPONSORS:

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Overview

- Problem Statement
- Bottom Line Up Front
- Background
- Requirements
- High-Level System
- Operational Scenarios
- Recommendations
- Future Work
- Summary

Problem Statement

- The U.S. Air Force lacks capability to quickly process large quantities of video in support of disaster relief
- Current solution is to have UAV fly over terrain following disaster to gather up to 12 hours of video
- Human analysts watch this video continuously for the duration of video in effort to identify anomalies and/or areas of interest

- Current solution:
  - "...death by video" ~ Ms. Biernesser

- Big Data Problem!!!

Bottom Line Up Front

- Literature review
- Evaluation of 3 types of imagery analysis algorithms
- Conceptual system design
- Feasibility study
- Conclusion
  - **Existing technology has not advanced to the level required to meet performance metrics for the functional specifications desired by sponsor**

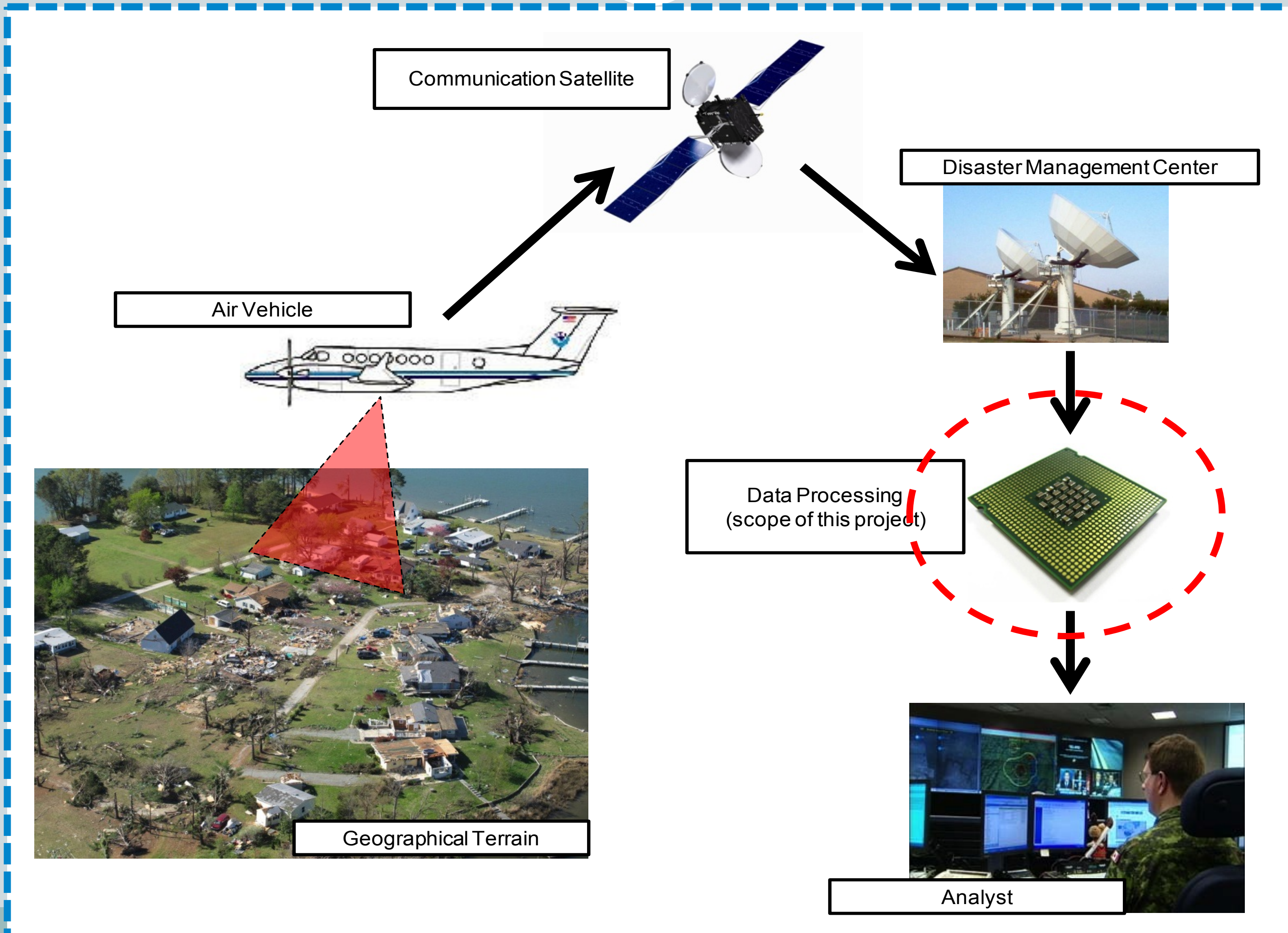
Scope

- Project will focus on developing the high order conceptual design of software that can process 12 hours of video for damage detection
  - *“Tell me **how** this could be done” ~Ms. Biernesser*
  - *“The Air Force has been flying around the forest of this problem and keeps getting smacked in the face with branches” ~Ms. Biernesser*
- Project will only concern deriving the feasibility of imagery analysis algorithms and software design
  - No hardware solutions

Approach

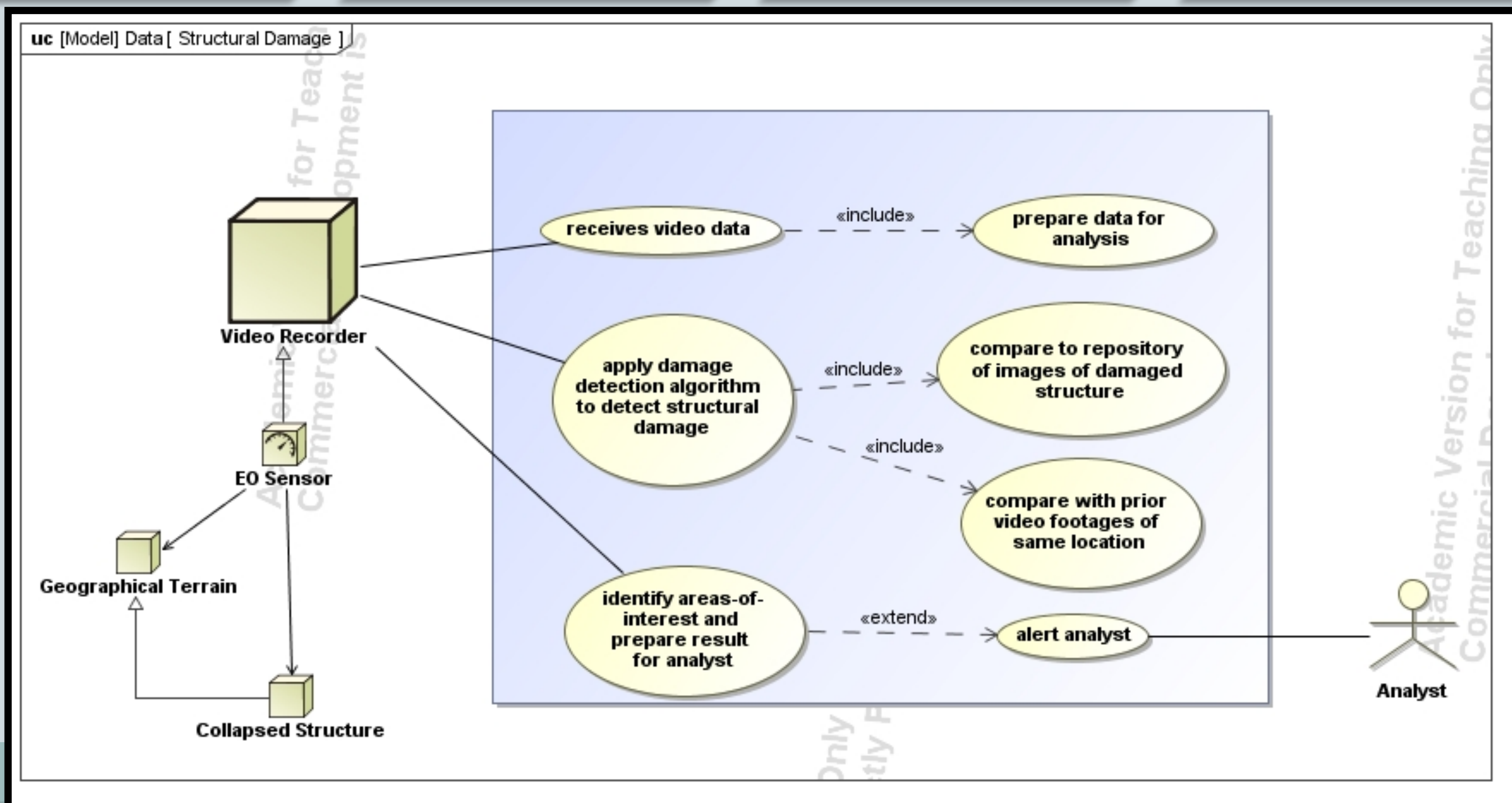
- Met with sponsor
  - Defined problem and scope
  - Developed high-level requirements
  - Identified system restrictions & constraints
- Literature research
- Separated system into 4 stages
- Identified project risks and mitigation strategies
- Sponsor approved deliverables
  - Conceptual System Design
  - Feasibility Study

Operational Concept



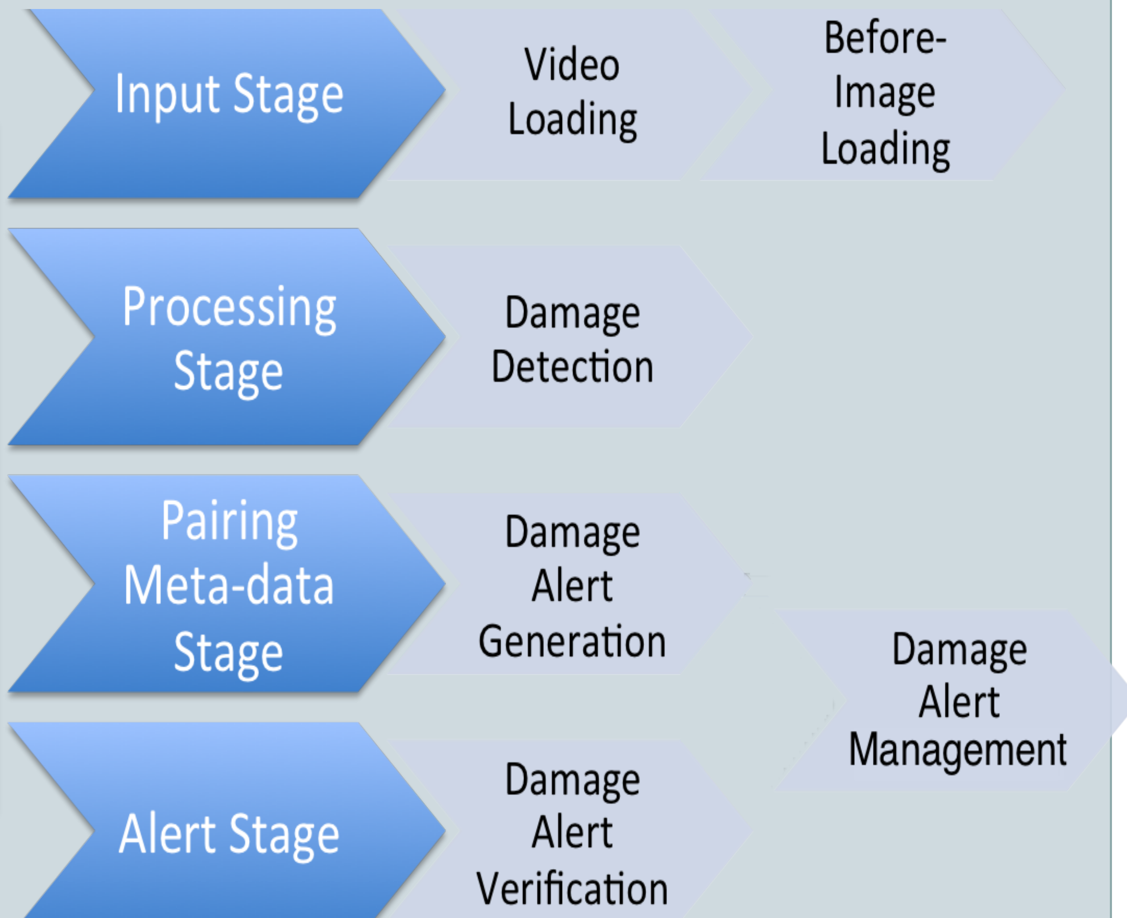
High-Level System Design

Input Stage → Processing Stage → Pairing Meta-Data Stage → Alert Stage

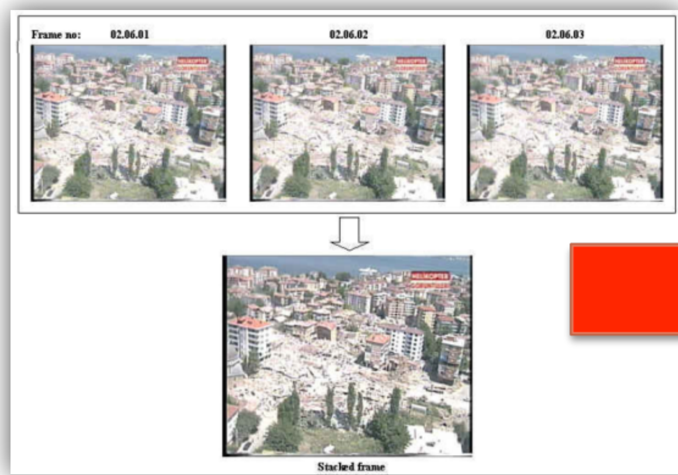


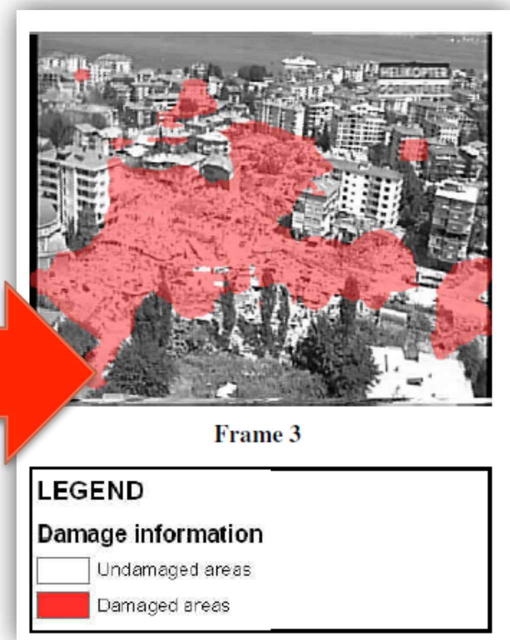
Functional Capabilities

- The system shall accept electro-optical (EO) and infrared (IR) video feeds.
- The system shall process up to 12 hours of video.
- The system shall be able to detect anomalies in video footage.
- The system shall be able to alert users when an anomaly is detected in the video feed.



General System Function





Input:
Frame grabbing
Image enhancement

Processing:
Featured layers
Define threshold

Output:
Identify areas-of-interest

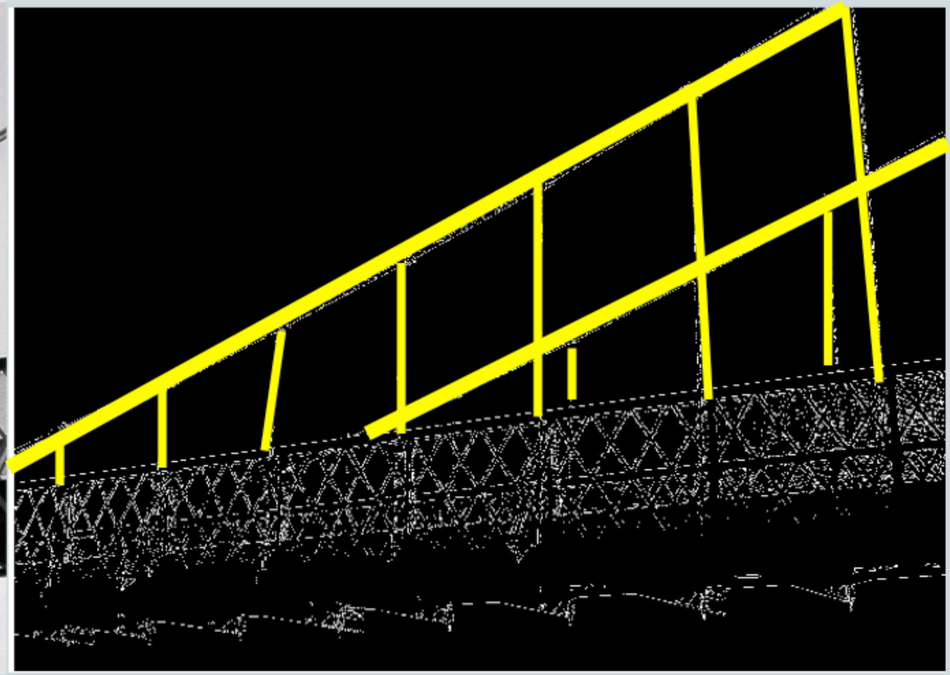
Mitigatable Disasters

- **Definition:** Can be forecasted with a certain amount of accuracy before they occur and action can be taken
- **Types:** Hurricanes, Monsoons, Floods, Snowstorm, Human-inflicted
- **<u>This means there's warning to collect prior-imagery</u>**

Canny Edge Detection Algorithm

- Developed as a means to detect edge lines and gradients for image processing
- Developed in 1986 and still considered state-of-the-art
- Main stages
  - Noise reduction through gaussian filtering
  - Determining gradients of images
  - Relate edge gradients
  - Trace valid edges
  - Hysteresis thresholding

Canny Edge Detection Algorithm



Canny Edge Detection Algorithm

- Pros
  - Can run in real time
  - Proven and tested approach
  - Works with color or monochromatic video
- Cons
  - Requires tweaking of parameters to get right
  - Requires large amount of processing power
  - Needs previous image for comparison

Un-mitigatable Disasters

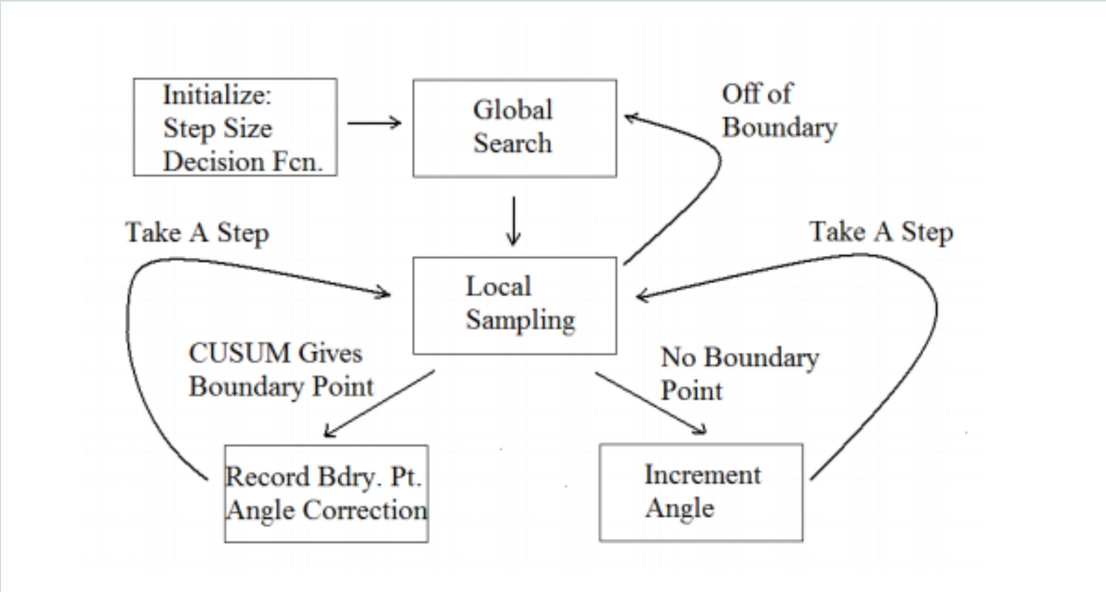
- Definition: Cannot be forecasted with accuracy before they occur
- Types: Earthquakes, Wildfires, Drought, Tsunami, Tornadoes, Sinkholes
- **<u>No warning: cannot collect prior-imagery</u>**

Boundary Tracking & Segmentation

- Segmentation is one of the most important problems in image processing
  - Partitioning an image into a small number of homogenous regions
  - Highlights important features to analyze
- Applications in geospatial target detection
- Region based vs Edge based
  - Region methods: Mumford-Shah & Chan-Vese
  - Edge methods: Image snakes

Boundary Tracking & Segmentation

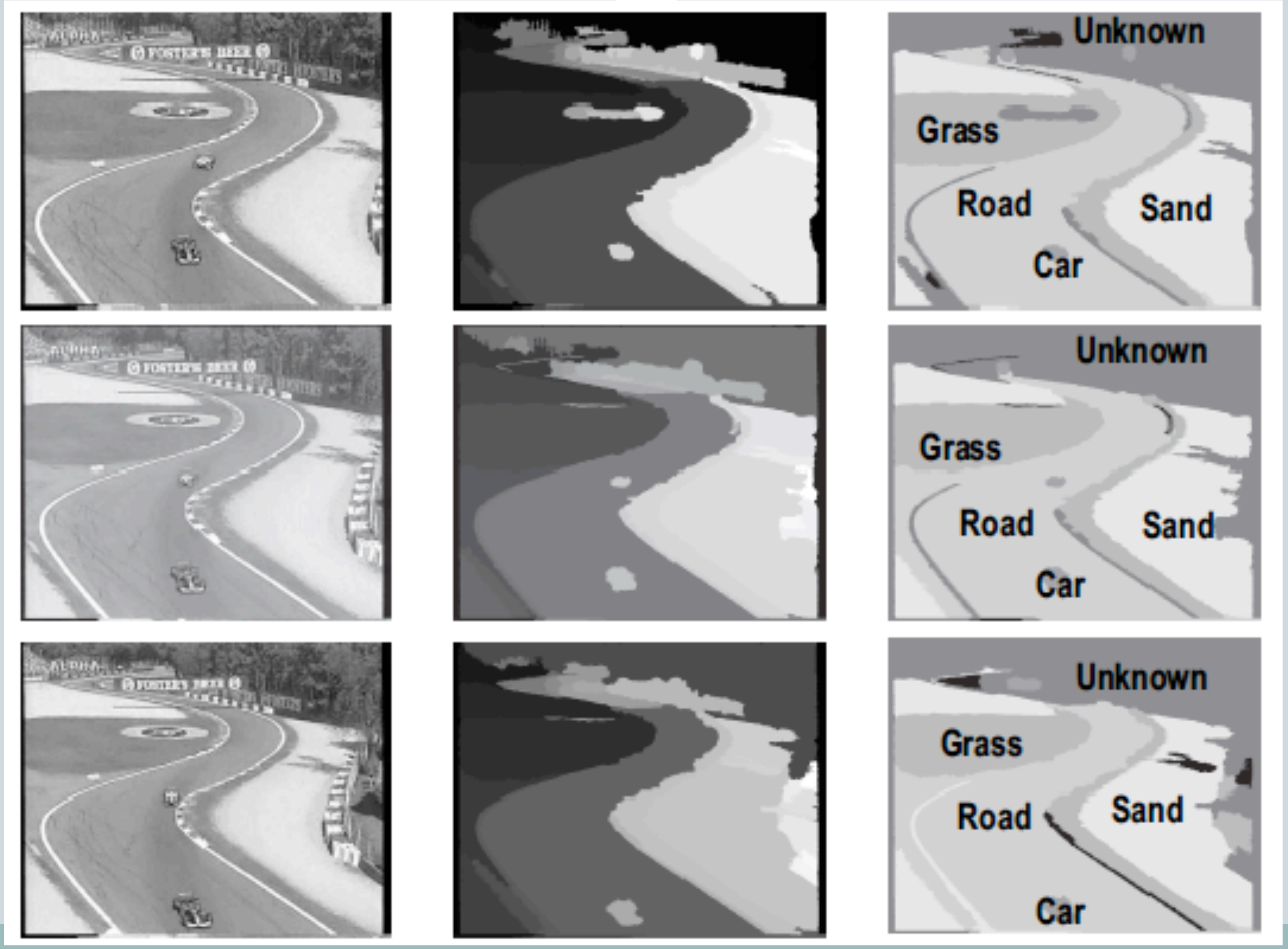
- Learn parameters
  - Update mean and variance of each region as new points are sampled
  - Sampling Gaussian noise



Boundary Tracking & Segmentation

- Pros
  - Allows for accurate boundary tracking even in highly noisy images
  - Can be used in conjunction with other types of algorithms
  - Do not need prior knowledge for image detection
- Con
  - For high-resolution images, computational times can be long, which can be overcome by doing sub-sampling

Genetic Algorithm



Genetic Algorithm

- Pros:
  - Flexible
  - Requires no prior imagery
- Cons:
  - Extremely dependent on object definition and characteristics

Algorithm Summary

- Canny Algorithm
  - Can run real-time
  - Requires large amounts of hardware and processing power in order to do so
- Boundary Detection
  - Can run in real-time however accuracy is 0.62 on f-scale (precision recall)
  - Humans are 0.79
- Genetic Algorithm
  - Takes 5-10 seconds per frame - would take 150-300x time of human

Recommendations

- Keep human analysts until technology and cost reach desired levels

- Processing time and accuracy still too slow to compete with speed of humans

- No single algorithm is good for all situations.

Currently best used as a System Support Tool

Summary

- Four key components to processing video: input, processing, meta-data pairing, and alerting
- Mitigatable disasters and unmitigatible disasters
- Recommendation: Keep using current process for videos
- Largest problem: humans are still fastest at processing video while maintaining accuracy
- Future work should focus on processing architectures and hardware

Future Work

- USAF needs to invest in feasibility study of their own to determine if it meets their mission requirements
- Extend further research into the specific algorithms described in CONOPS
- Research algorithms that can identify non-areas-of-interest
- Research hardware design
  - Hardware capability
  - Parallel hardware

Questions??

Back-Up

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Genetic Algorithm

$$Fitness(G) = \sum_{g_i} \mathrm{I}_M(g_i) + \sum_k \sum_{(g_i, gj), g_i R_k g_j} I_{R_k}(g_i, g_j)$$

- Optimal solution maximizes fitness equation
- G is the gene of interest
- $I_M(g_i)$ is the estimation function of gene g_i regarding low-level visual similarity
  - Similarity between the region of interest and an object that's been described
- $I_{Rk}(g_i, g_j)$ is the estimation function of spatial similarity between g_i and g_j in terms of R_k
  - Describes how well a relation holds between two regions

Dynamic Processing Allocation (DPA)

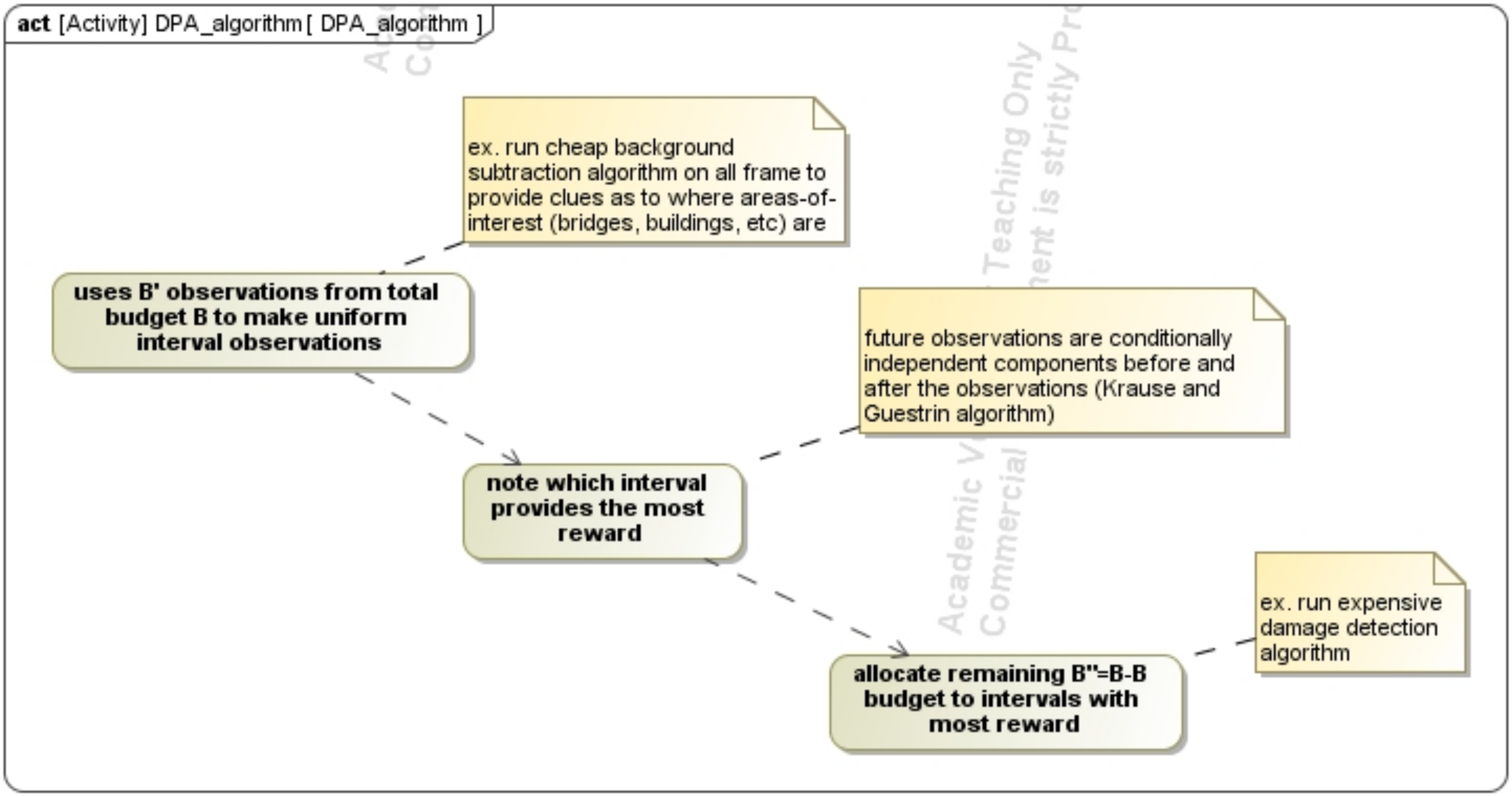
- A method for controlling processing to manage computing resources.
- Find a balance between SPEED and ACCURACY.
- Employs both “cheap” and “expensive” processing algorithm.
  - Cheap = less accurate, faster
  - Expensive = >90% accurate, slower; may be human analyst

DPA - How

- Employ second-order Markov model with node and state variable for each frame
- Similar to Hidden Markov Model, the observation of each frame depends on the previous
- Cheap algorithm
  - Background subtraction
- Expensive algorithm
  - Face detection
  - Moving object
- Run cheap algorithm on every frame
- Run expensive algorithm on consecutive uniform intervals of frame

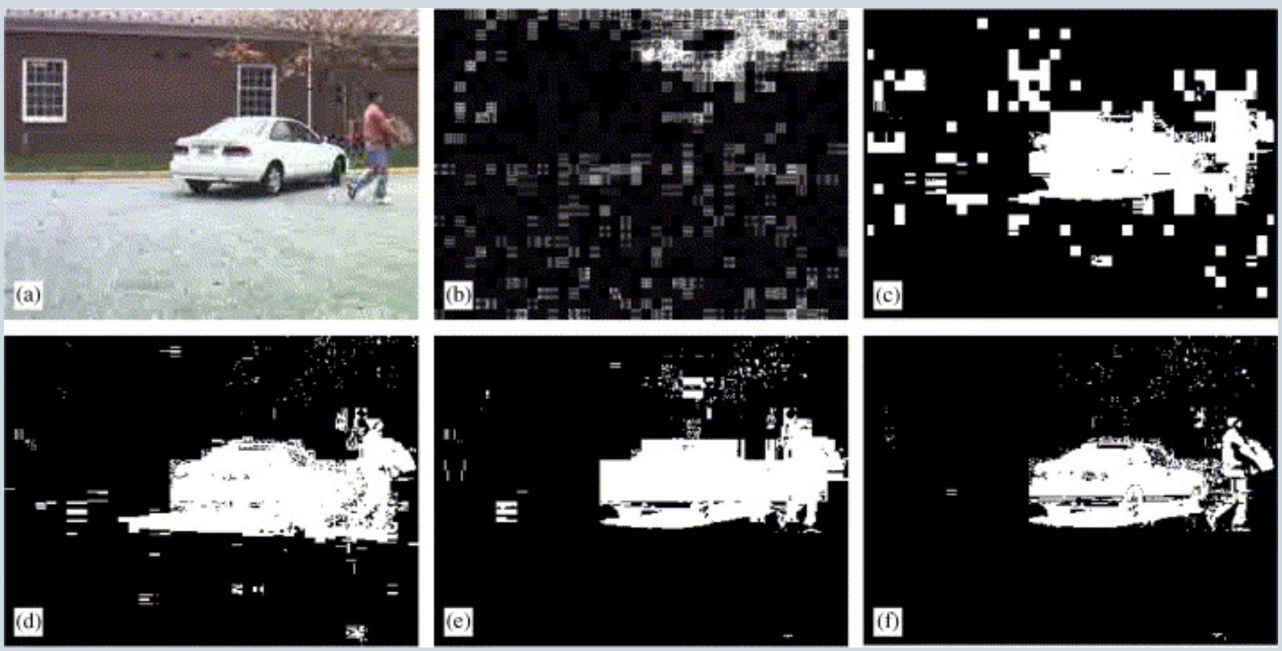
DPA PLANS WHERE TO EMPLOY THE MOST PROCESSING RESOURCES
-DIRECTS RESOURCES TO THE MOST RELEVANT PART OF THE VIDEO-

DPA - Algorithm



DPA - Background Subtraction

- Detection results on a compressed video: (a) original image, (b) standard deviations, (c) unimodal model , (d) MOG, (e) Kernel, (f) CB



http://www.sciencedirect.com/science/article/pii/S1077201405000057

DPA - Examples of Face Detection

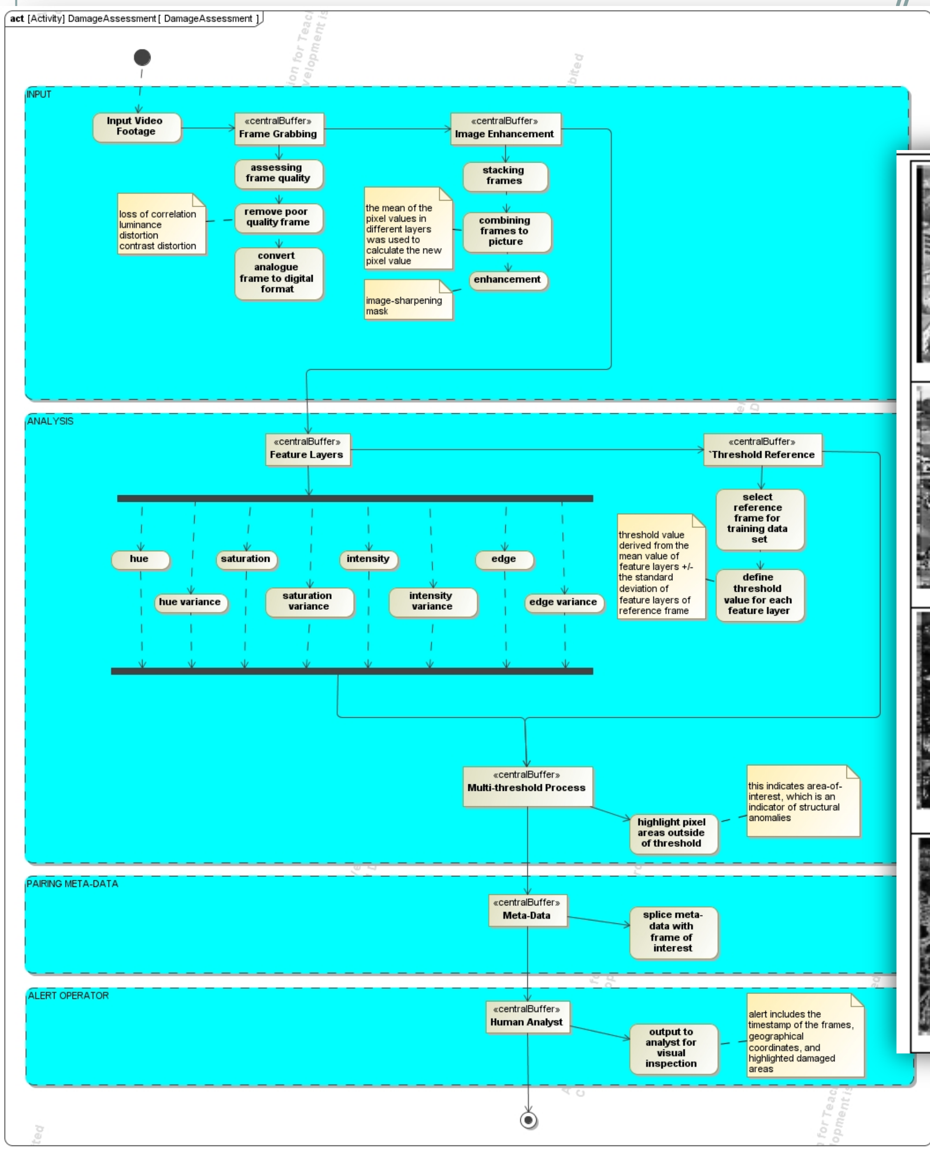
- Top-down knowledge-based method – determines relationship between structural features such as eyes, nose, and mouth.
- Bottom-up feature-based method – seek invariant structural features such as eyebrows, hair texture, and skin color.
- Template-based method – compare faces with input image.
- Appearance-based method – use statistical analysis and machine learning techniques.

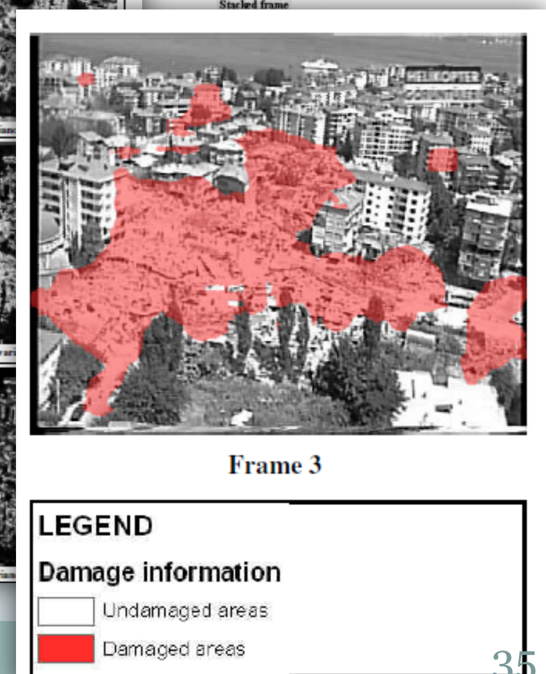
SAME ALGORITHM APPLIES TO DAMAGE DETECTION

DPA - Pros & Cons

- Pros
  - Employs multiple algorithms – the best of both
  - Balance between accuracy vs speed
  - Can be applied to videos with large number of frames
  - Can set limit to processing resources
- Cons
  - Employs multiple algorithms – complicates logic
  - Not as fast as some algorithms
  - Not as accurate as some algorithms
  - Not for simultaneous capture and processing

General Approach





High-Level Project Risk

Risk	Mitigation Strategy	Likelihood	Impact
Short duration of the performance period in the event the schedule slips	Redefine scope as needed to account for period of performance	Low	Medium
Availability of sponsor for feedback on deliverables	Utilize both sponsors to review deliverables	Low	Low
Availability of desired software packages for developing deliverables	Identify additional software with similar capabilities that are more readily available as well as utilize SEOR labs if available and loaded with desired software	Low	Low
Availability of SMEs to provide information on	Work early with Sponsor to leverage any contacts that are available; identify SMEs needed early on	Medium	Medium

Schedule

GANTT CHART

	Task Name	Start	Finish
1	**1 Complete SYST699 Project**	**Mon 1/28/13**	**Fri 5/10/13**
2	**1.1 Write Proposal**	**Fri 2/1/13**	**Mon 2/25/13**
3	1.1.1 Meet With sponsor	Fri 2/1/13	Fri 2/1/13
4	1.1.2 Gather Requirements	Fri 2/1/13	Tue 2/12/13
5	1.1.3 Define Project Scope	Fri 2/1/13	Fri 2/15/13
6	1.1.4 Study Current Operations	Fri 2/1/13	Fri 2/1/13
7	1.1.5 Define Necessary Deliverables	Fri 2/1/13	Fri 2/15/13
8	1.1.6 Complete Team Meetings	Mon 2/4/13	Tue 2/19/13
9	1.1.7 Define Stakeholders	Fri 2/1/13	Fri 2/15/13
10	1.1.8 Review with Sponsor	Thu 2/21/13	Mon 2/25/13
11	**1.2 Create Proposal Presentation**	**Mon 2/4/13**	**Mon 2/18/13**
12	1.2.1 Create Slides	Thu 2/14/13	Sun 2/17/13
13	1.2.2 Complete Team Meeting	Sun 2/17/13	Sun 2/17/13
14	1.2.3 Rehearse Presentation	Sun 2/17/13	Mon 2/18/13
15	**1.3 Complete CONOPS**	**Mon 2/4/13**	**Sat 3/23/13**
16	1.3.1 Brainstorm New Methods of Operation	Mon 2/4/13	Thu 2/14/13
17	1.3.2 Define Operational Scenarios	Fri 2/15/13	Fri 3/1/13
18	1.3.3 Define Architectures	Mon 3/4/13	Wed 3/13/13
19	1.3.4 Develop CONOP illustrations	Thu 3/14/13	Tue 3/19/13
20	1.3.5 Sponsor Review	Wed 3/20/13	Sat 3/23/13
21	**1.4 Complete AoA**	**Sun 3/17/13**	**Tue 4/30/13**
22	1.4.1 Research design alternatives	Sun 3/17/13	Tue 3/26/13
23	1.4.2 Develop System Logic For All Options	Wed 3/27/13	Thu 4/4/13
24	1.4.3 Risk Analysis	Fri 4/12/13	Mon 4/15/13
25	1.4.4 Effectiveness Analysis	Tue 4/16/13	Wed 4/24/13
26	1.4.5 Lessons Learned	Thu 4/25/13	Tue 4/30/13
27	1.4.6 Sponsor Review		
28	**1.5 Interim Progress Report (IPR)**	**Mon 3/11/13**	**Mon 3/18/13**
29	1.5.1 Create Slides	Mon 3/11/13	Fri 3/15/13
30	1.5.2 Rehearse Presentation	Sat 3/16/13	Sat 3/16/13
31	1.5.3 Give Presentation	Mon 3/18/13	Mon 3/18/13
32	1.5.4 Meeting with Instructor		
33	**1.6 Create Website**	**Sun 2/17/13**	**Fri 5/10/13**
34	1.6.1 Write Code	Sun 2/17/13	Mon 2/18/13
35	1.6.2 Add Team Bio Information	Tue 2/19/13	Tue 2/19/13
36	1.6.3 Add Periodic Updates	Tue 2/19/13	Thu 5/9/13
37	**1.7 Prepare Final Report**	**Mon 4/8/13**	**Fri 5/10/13**
38	1.7.1 Write Report	Mon 4/8/13	Sun 5/5/13
39	1.7.2 Prepare Final Presentation Slides	Wed 4/17/13	Sun 4/28/13
40	1.7.3 Rehearse Presentation	Mon 4/29/13	Mon 5/6/13
41	1.7.4 Give Presentation	Fri 5/10/13	Fri 5/10/13
42	1.7.5 Sponsor Review	Mon 4/29/13	Thu 5/2/13