# CANON: Decision Support System Design Review

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M B A R I

# *Presentation Outline*

- Introduction to CANON and the DSS
- Motivating Scenario
- User Requirements
- Inference and Problem solving challenges
- Development Approach
- Development Staging and Resource Loading
- Conclusion

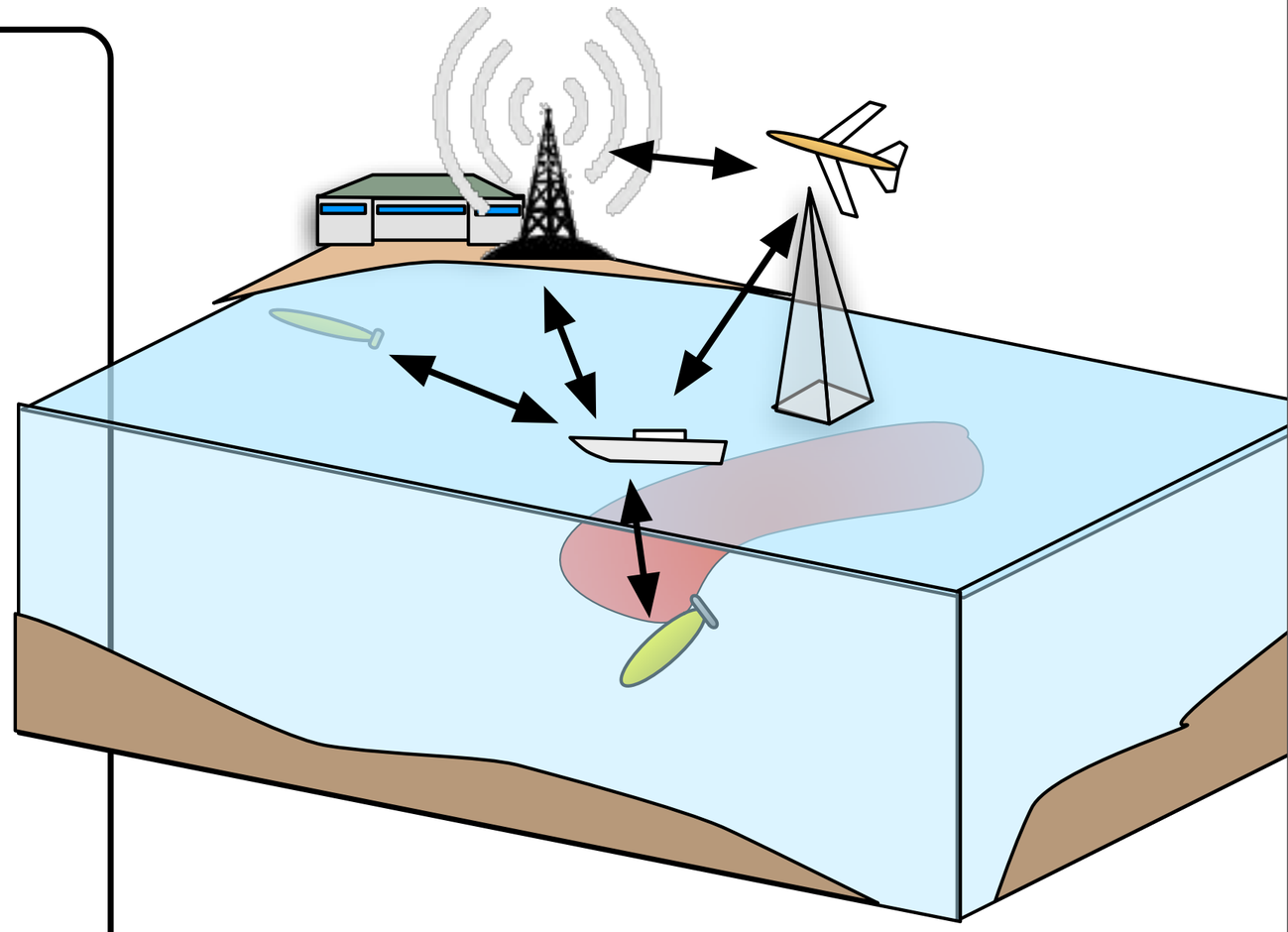
# *Desired Outcomes of this Meeting*

- To articulate clearly the need and general approach for a software product for a major MBARI initiative
- To obtain participant feedback on technical approaches which will support user requirements
- Charge to this group
  - Feedback on the general approach, does it make sense?
  - Are we missing anything functionally or technologically?
  - Are their lessons to be learned from developing tools/techniques in other domains?

# *What is CANON?*

The vision of CANON over the next 5-10 years is for intensive process-driven, ecologically-oriented field experiments utilizing a multi-platform, multi-sensor, multi-scale, multi-disciplinary approach.

Technology development will concentrate on rapidly deployable autonomous platforms, innovative sensors and samplers and software.



# *What is CANON?*

- Multi-disciplinary science investigation of multi-scale ocean phenomena. Five science case studies identified:
  - Oxygen Minimum Zone (OMZ)
  - Harmful Algal Blooms (HAB)
  - Thin Layers (TL)
  - Zooplankton (ZOO)
  - Open Ocean Eddies (OO Eddie)

- For a given CANON case study (Map, Tag, Track):
  - Identify the phenomena as it is developing,
  - Characterize boundaries,
  - Target a 'patch' to study processes
  - Sample the water (repeatedly & adaptively)
  - Follow the targeted patch to study it's changes bio-geochemically through time.

# *What is a Decision Support System (DSS)?*

- A tool to aid decision making by processing data that augments human cognitive capabilities for problem solving
  - With an AI perspective, it involves the use of inference, event notification and exploration of alternative scenarios
  - Interactive: human and computer bring their best traits to bring about a solution
  - More than a standard informational display
- Experience of NASA's Mars Rover program:

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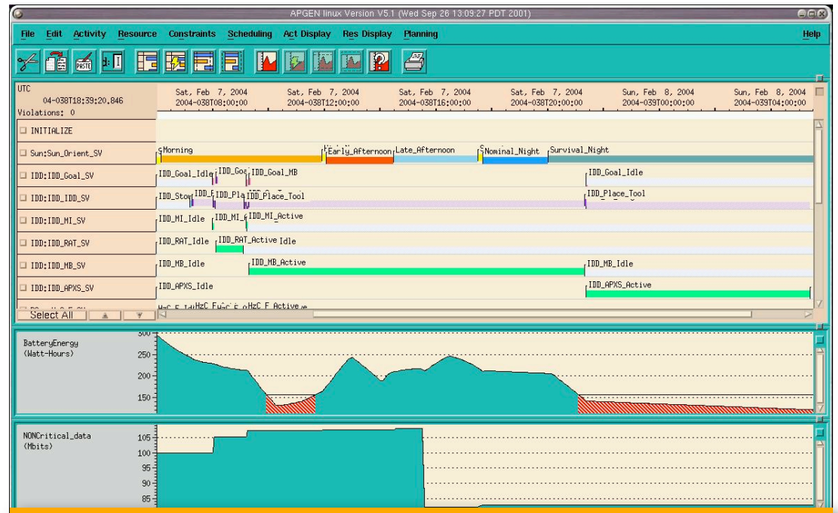


MER MAPGEN: Mixed-initiative Activity Plan GENerator

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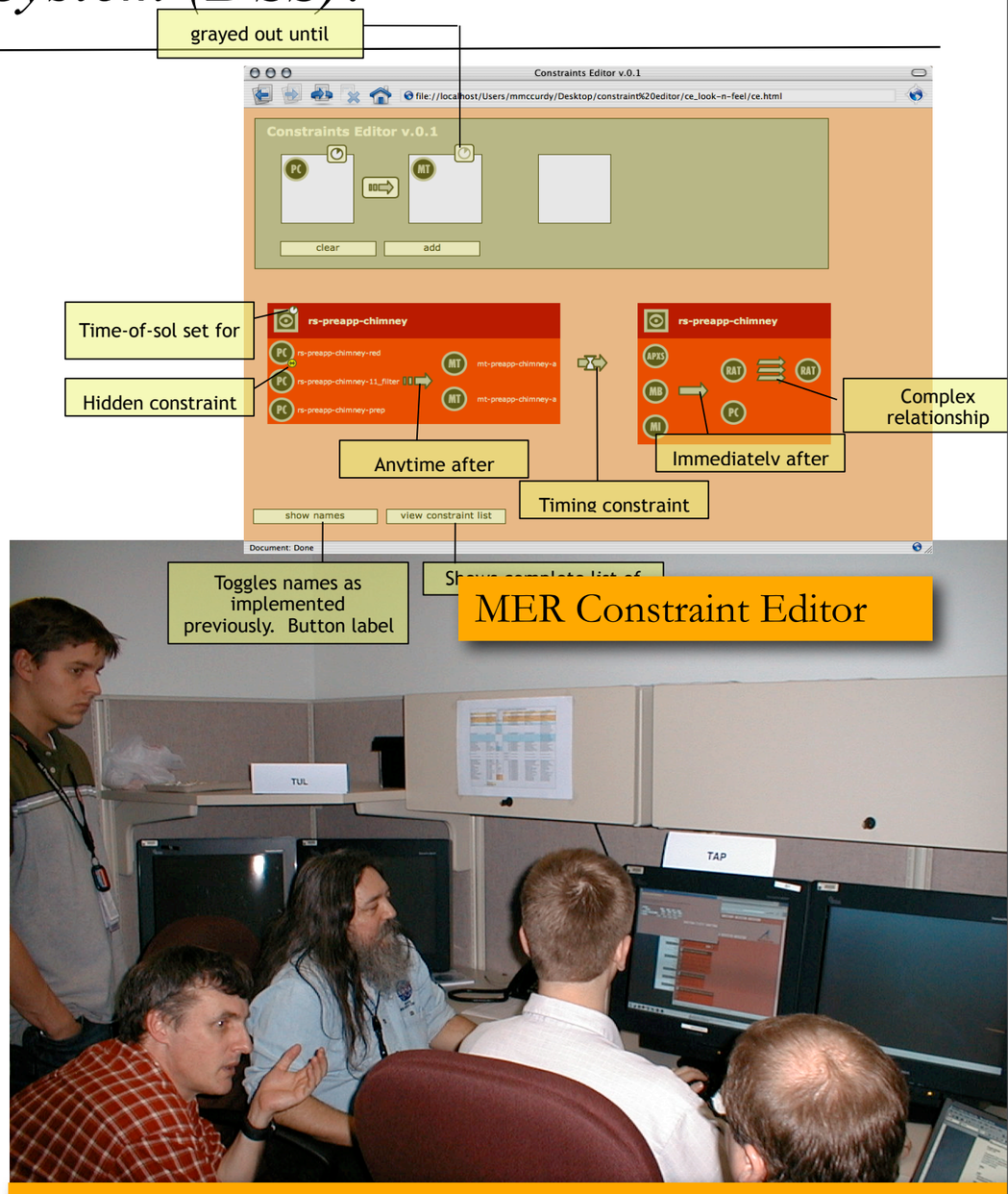


MER PI Steve Sqyures with John Bresina and Jeff Norris on first day of MER science ops Sol 8 Jan 15 2004

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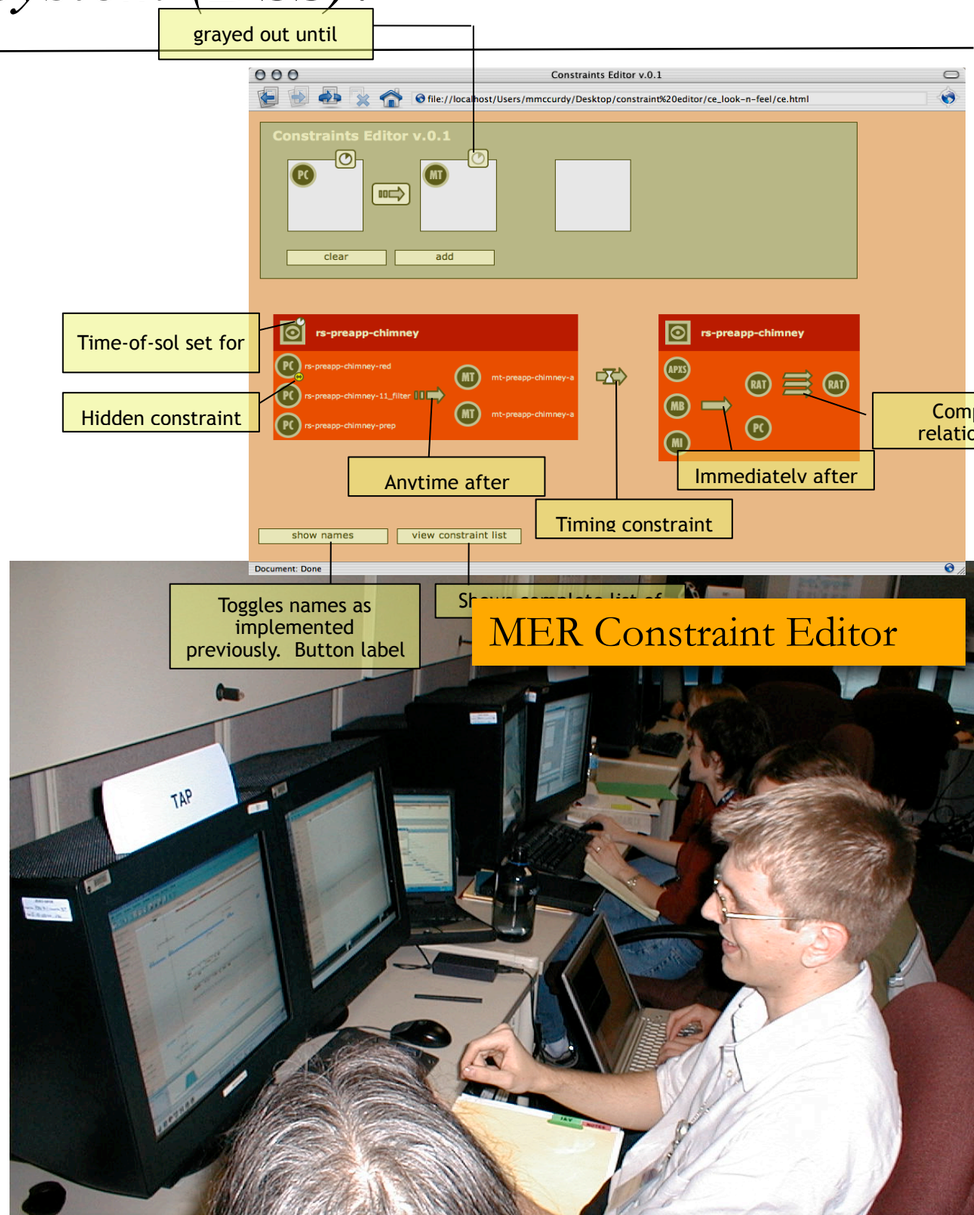



Tactical Activity Planner Jeff Norris Planning with MAPGEN Jan 2004

# *Why do we need a DSS for CANON?*

Growing complexity of multi-disciplinary experiments requires integration of data synthesis and inference

To improve efficiency:

- Better ways of doing science by:
  - encapsulating complexity
  - planning interfaces
  - operational details
- Integrate processes, decision making and automate-able expertise that would traditionally be dispersed among different specialists

Brings together existing MBARI technology within a framework that is current and scalable for technology transfer

# *What we envision for the CANON DSS*

- A tool that will
  - augment situational awareness
  - inform asset deployment
  - integrate data management
  - enhance collaboration

  targeted for ocean science field experiments.
- Two primary components
  - augmenting previous efforts at data management
  - automated inference capabilities for managing multiple assets at sea
- A collaborative development effort between a number of MBARI PI groups, Engineering, Operations and external collaborators

# An Illustrative Example

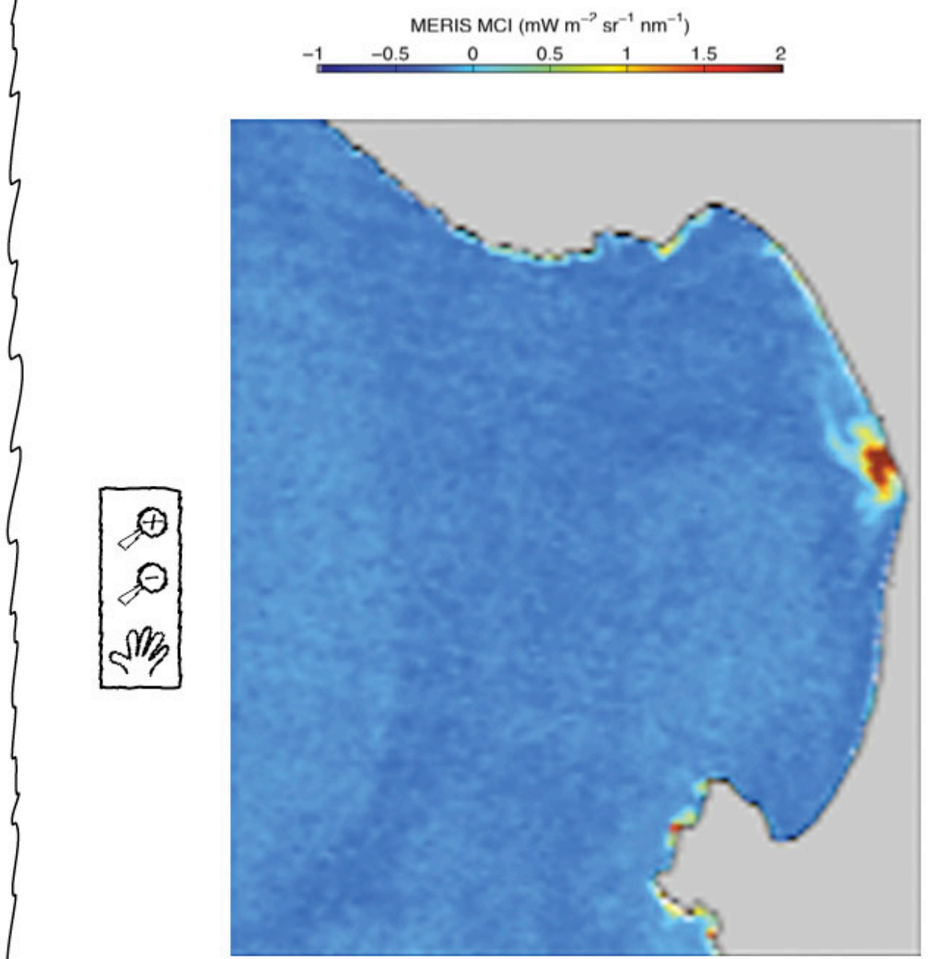
## Data

Data | Planning | Logistics

- Data Sources
  - [x] MODIS
  - [ ] HF Radar
  - [ ] MERIS
  - [ ] Chlorophyll
  - [ ] Current
  - [ ] Provenance
  - [ ]
  - [ ]
  - [ ]
  - [ ]
  - [ ]
- Live Data
  - + [ ] DSS Plan Data
    - [ ]
    - [ ]
- Forecast
  - [ ] 4D Bio-Physical Model
  - [ ]
  - [ ]

Event Notification

## Visualization



MBARI

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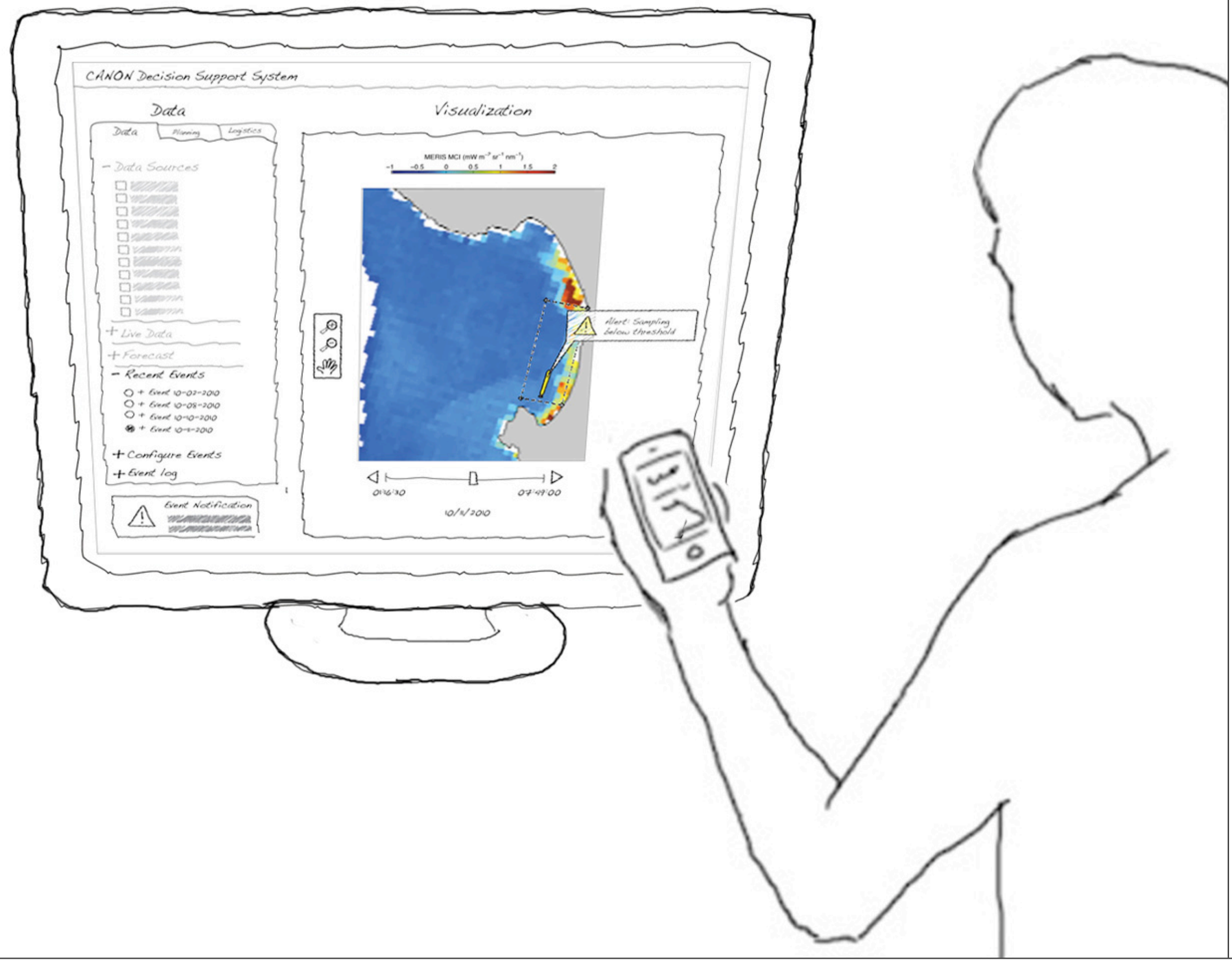

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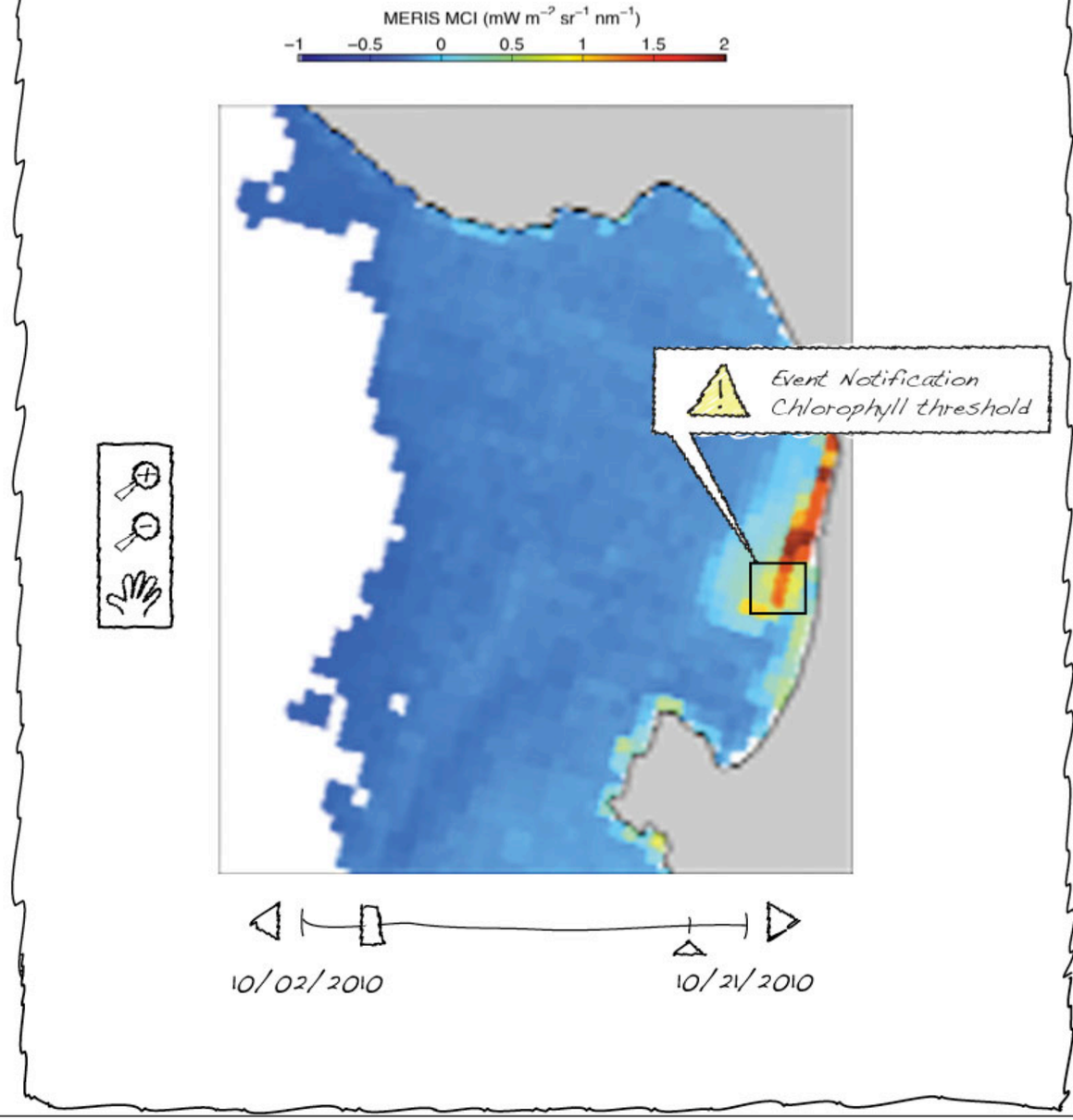


MBARI

# An Illustrative Example

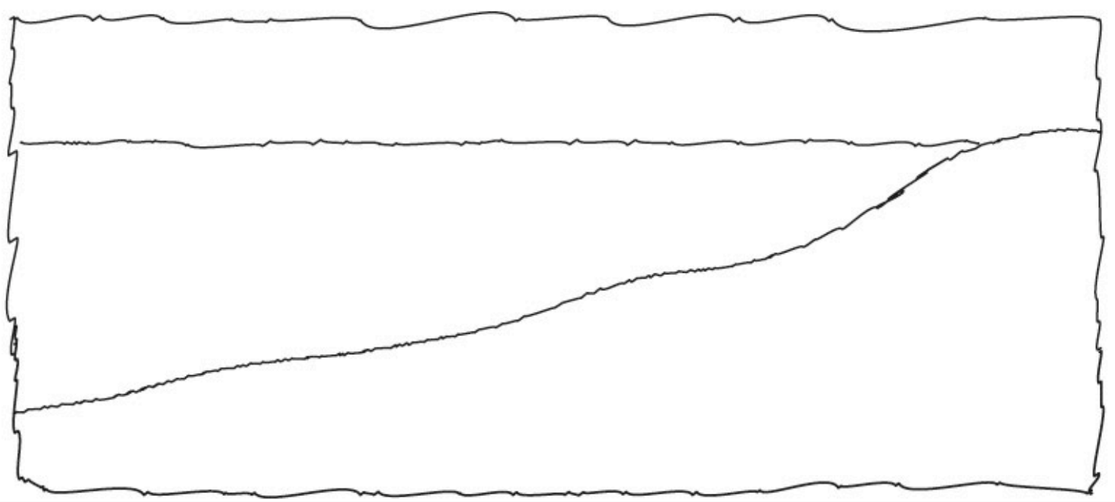
CANON Decision Support System

Planning

Data | Planning | Logistics

+ AUN-CTD
+ LRAUN
+ ASV
- ROV
  + Ventana
  + Tiburon
  + [illegible]
+ Drifters
+ Gliders
+ ESP
+ Ships

Visualization



MBARI

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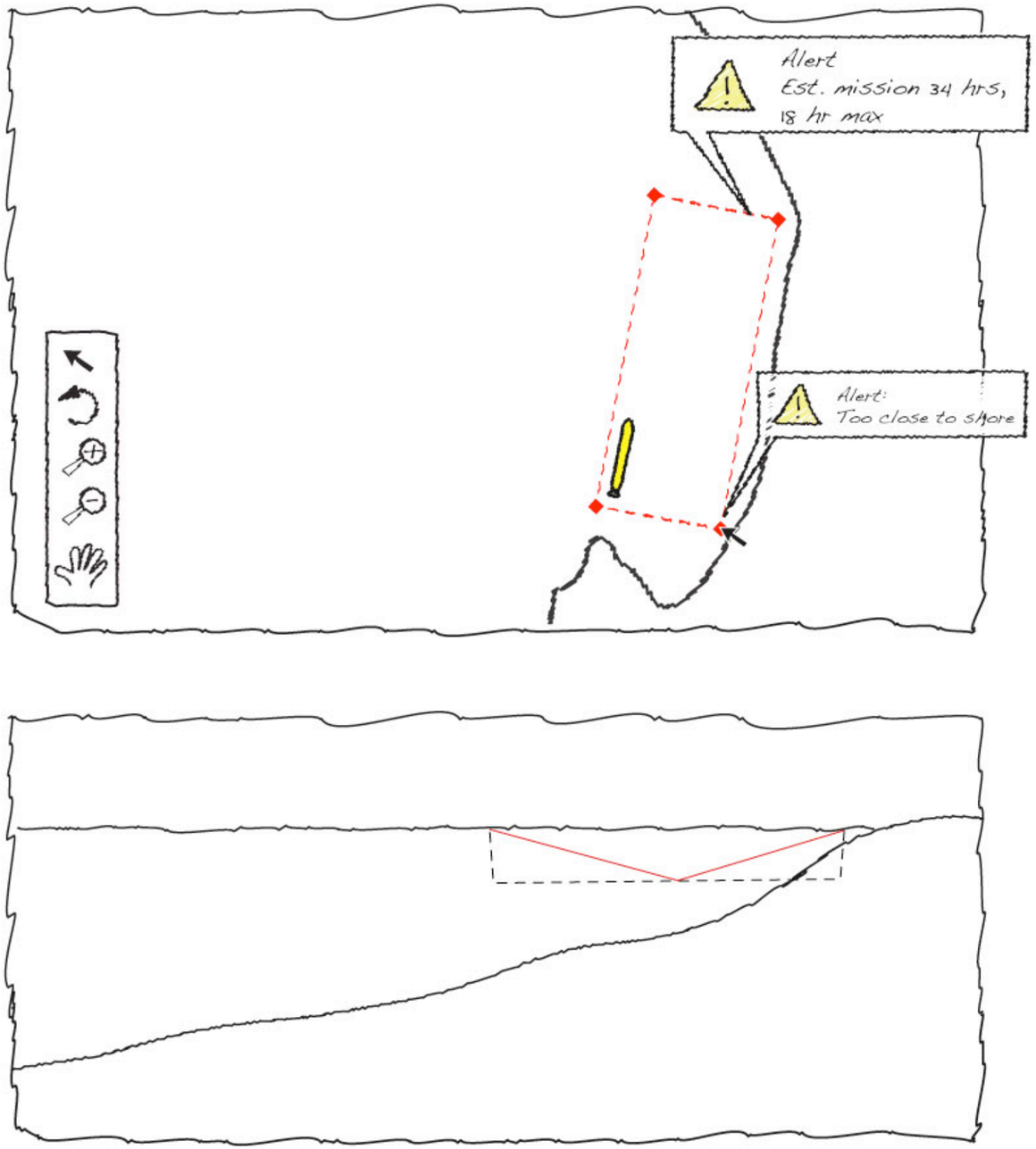


MBARI

# An Illustrative Example

CANON Decision Support System

Planning

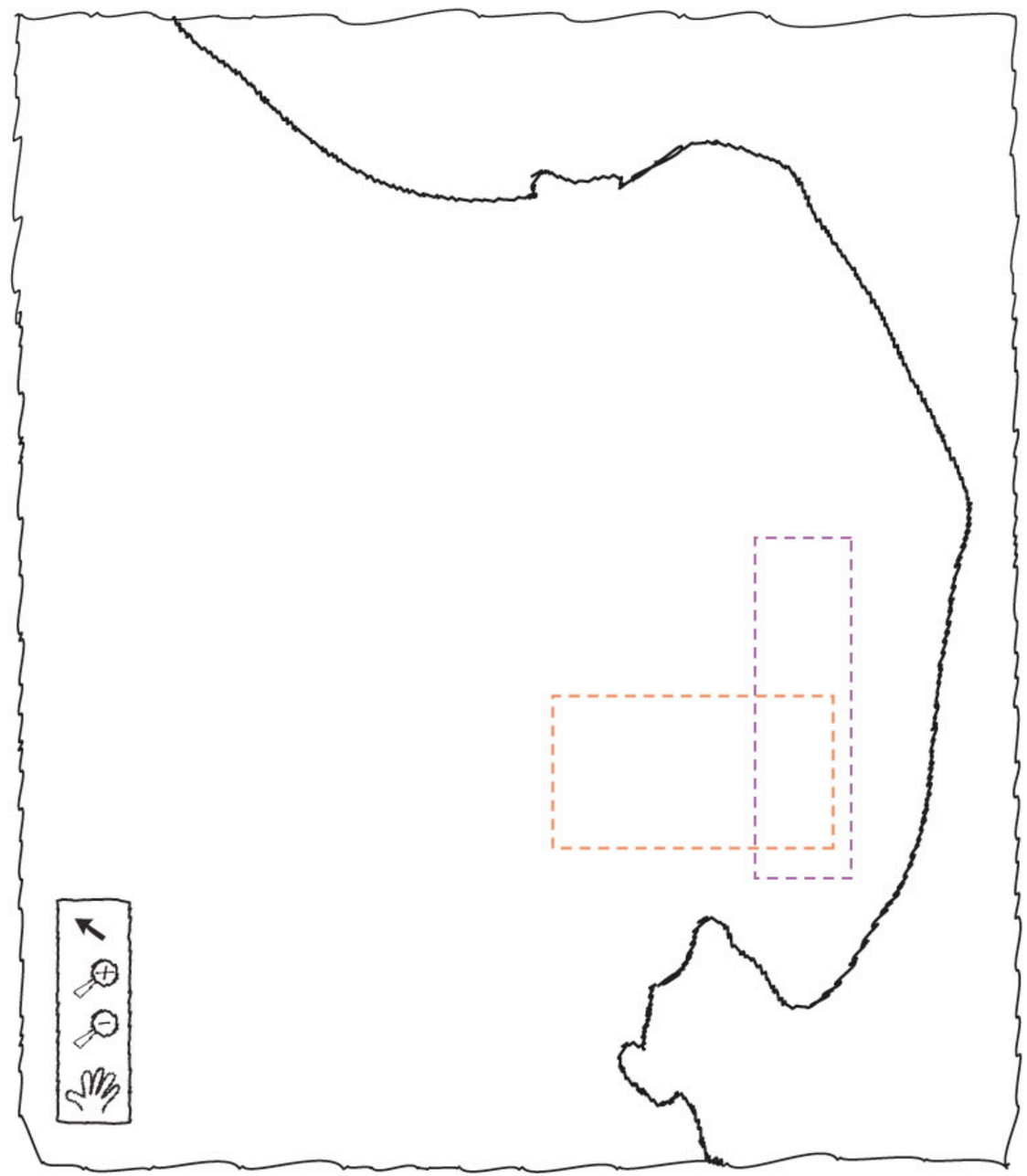
Data | Planning | Logistics

+ AUV-CTD ⚠
+ LRAUV
+ ASV
+ ROV
+ Drifters ⚠
+ Gliders
+ ESP
+ Ships

Generate Script

Submit Plan

Visualization



MBARI

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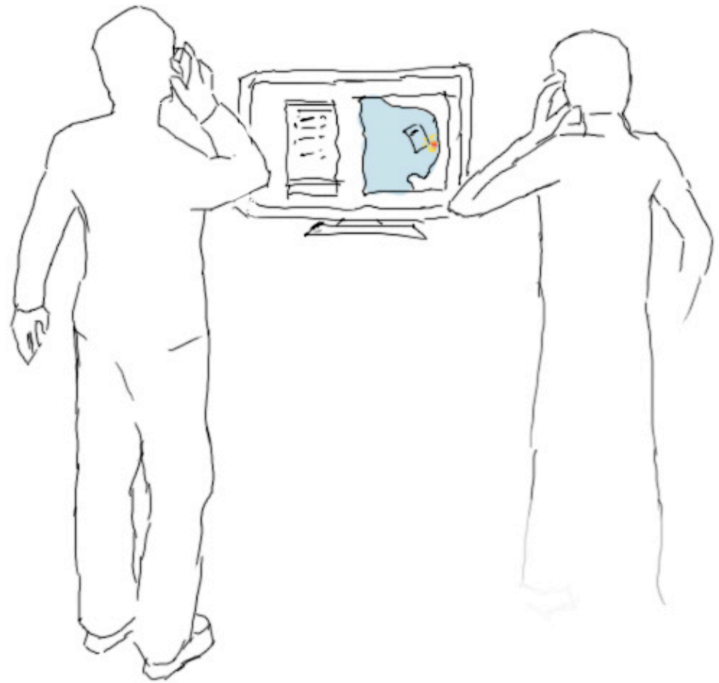

MBARI

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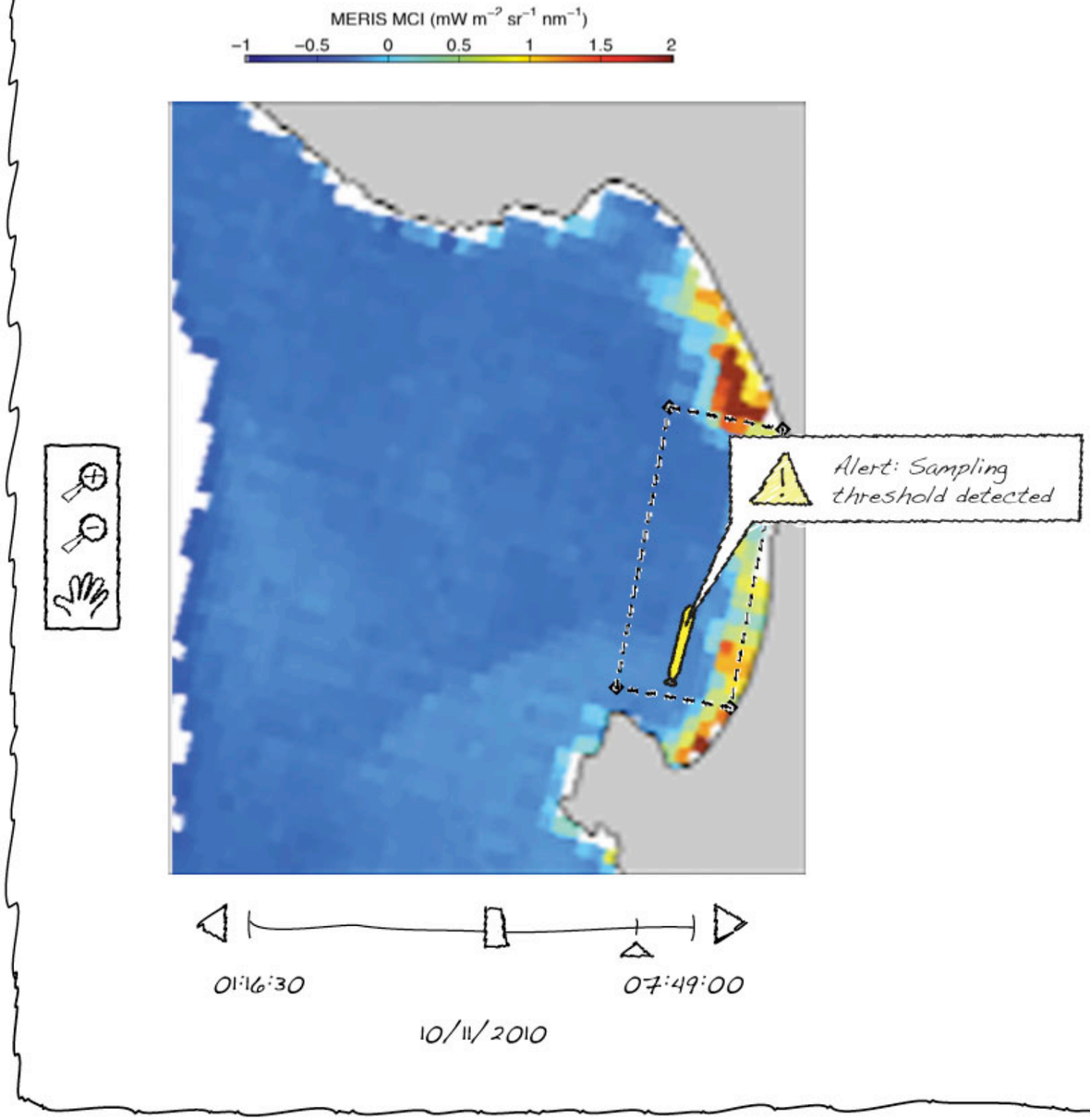
  - [ ] [redacted]
- + Live Data
- + Forecast
- − Recent Events
  - + Event 10-02-2010
  - + Event 10-08-2010
  - + Event 10-10-2010
  - + Event 10-11-2010
- + Configure Events
- + Event log

Event Notification
[redacted]

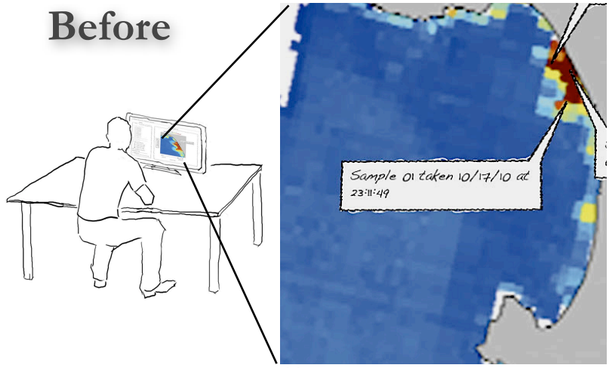
## Visualization



MBARI

# *An Illustrative Example*

## Before

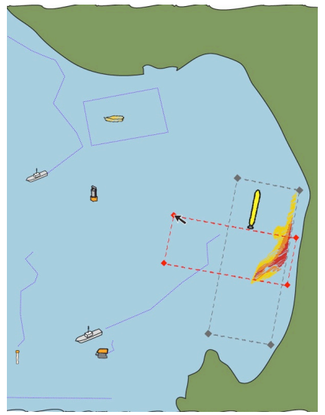



- Data collection
  - recent events
  - historical
- Analysis
- Planning
- Simulation experiments (VPE)
- Populating database(s)

## After

- Replay
- Analysi
- Archival use

## During a Field Experiment



- Situational awareness
- Planning
- Collaboration
- Annotation

MBARI

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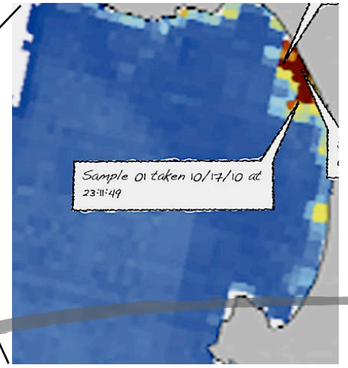


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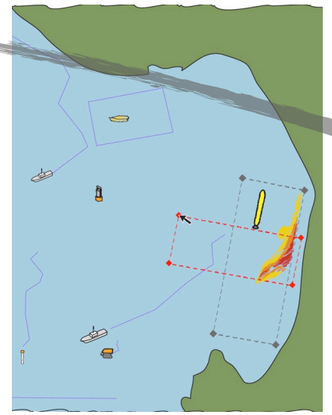

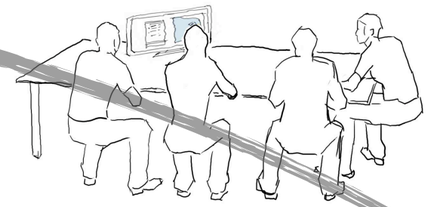

- Situational awareness
- Planning
- Collaboration
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## After

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# *CANON DSS: Requirements*

**Level 0**

1. The DSS will be a shore based tool to provide situational awareness, planning and coordination (robotic and human) capability for ocean science field experiments.
2. The DSS will be built in a way that is sustainable at MBARI and for the community at large.

**Level 1**

1. The DSS will incorporate data from diverse sources (including satellite data) to provide situational awareness.
2. Existing backbone computational infrastructure including those used in previous field experiments and available at MBARI will be used by the DSS.
3. For situational awareness, the DSS will provide identical views to multiple simultaneous users.
4. The DSS will generate event notifications driven by environmental observations.
5. The ability to contrast intended plans with actual execution is critical.
6. The spiral development model will be used with iterative refinements to the tool driven by actual user use in field and simulation experiments.
7. Final versions of DSS will be portable for use outside MBARI.

# *CANON DSS: Requirements*

**Level 2**

1. The DSS will have the capability to re-target assets in the water from shore.
2. DSS visualization should be able to layer data to augment or remove information as needed.
3. Vehicle tracks in the water should be visible.
4. Image annotation capability for sharing or private viewing will be provided by the DSS.
5. Automated planning capability will be necessary to target where and what a platform should do
6. The DSS will provide the capability for collaborative field work including discussion boards, posting of data and a voting capability.
7. To validate its utility and efficacy, the DSS will be tested yearly in field deployments for CANON and/or other experiments in the Monterey Bay.
8. DSS development will need to be responsive to evolving science requirements.

**Level 3**

1. The DSS will attempt to provide a cost metric for deploying assets for logistics planning.
2. Lessons learned from the Metrology community should be factored into the DSS design.

# *Problem Characteristics for Inference and Control*

- Goal oriented commanding
- Hybrid (human/machine) decision making
- Distributed reasoning
- Heterogenous mobile assets
- Poor to limited communication with most assets
- Desk-based synoptic views

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- Goal oriented commanding
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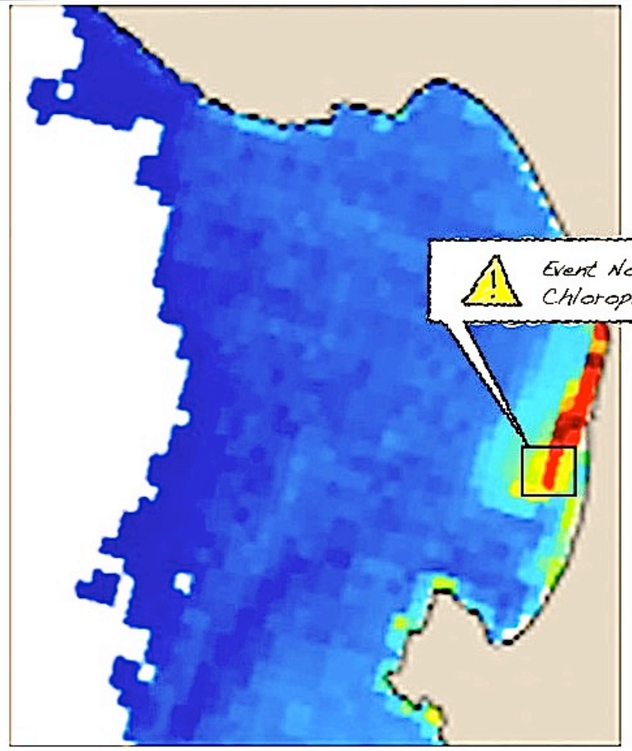
- Desk-based synoptic views

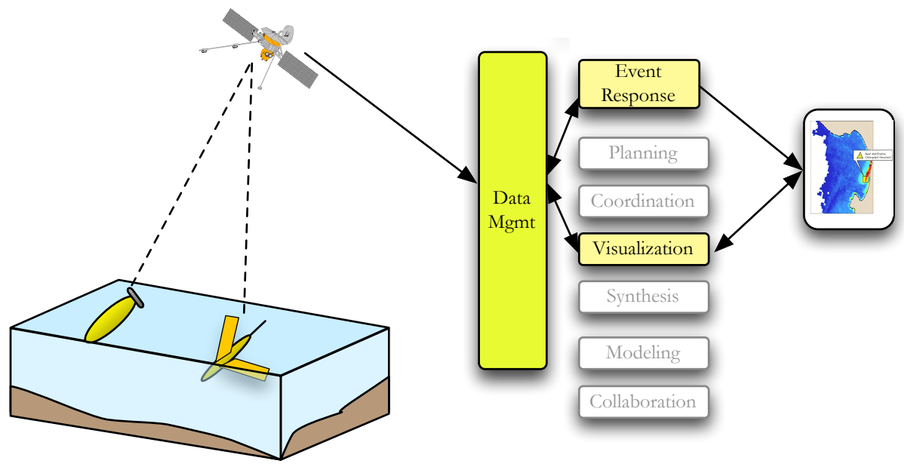
- Loosely coupled *heterogenous* vehicles
- Each vehicle could have onboard plan synthesis capability
- Limited information exchange
- Human as a separate 'agent' brings substantial cognitive capability
- Synoptic views are generated by the fusion of disparate map data, combined with onboard autonomy

# *Planning and Inference -1: Event Response*

- Integrate existing statistical Machine Learning techniques with incoming data stream
  - trigger notification based on customized thresholds
- Identification models built a priori based on existing training sets
- Customized feature sets to individual science needs
- Leverages existing expertise and algorithms (SmartSampler)

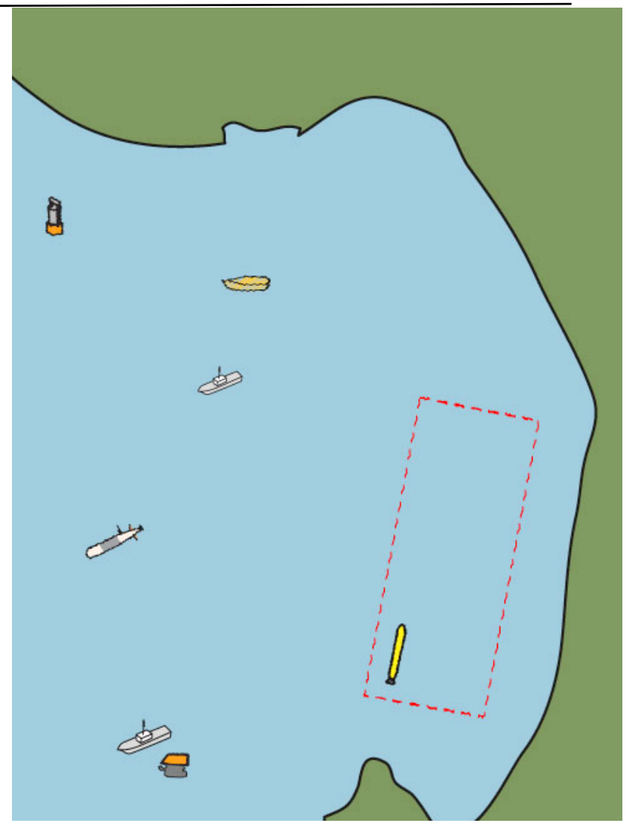


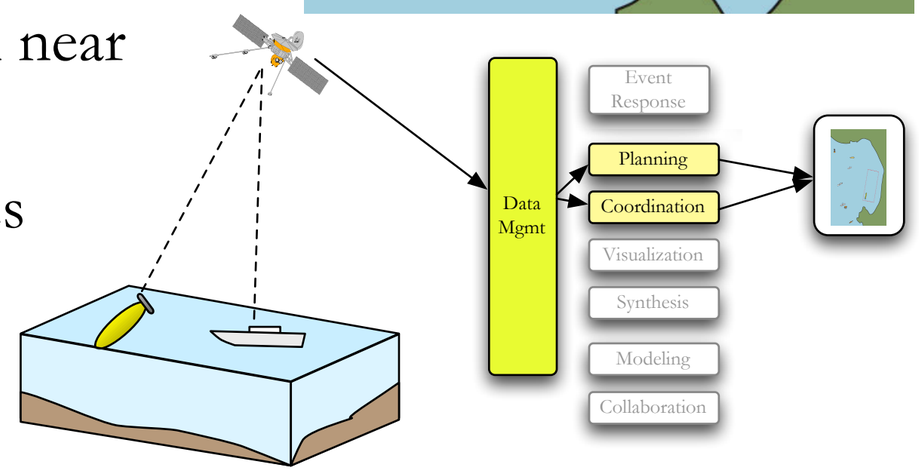

- Key research agenda:
  - Hidden Markov Model synthesis



# *Planning and Inference -II: Multi-vehicle Mixed-Initiative Control*

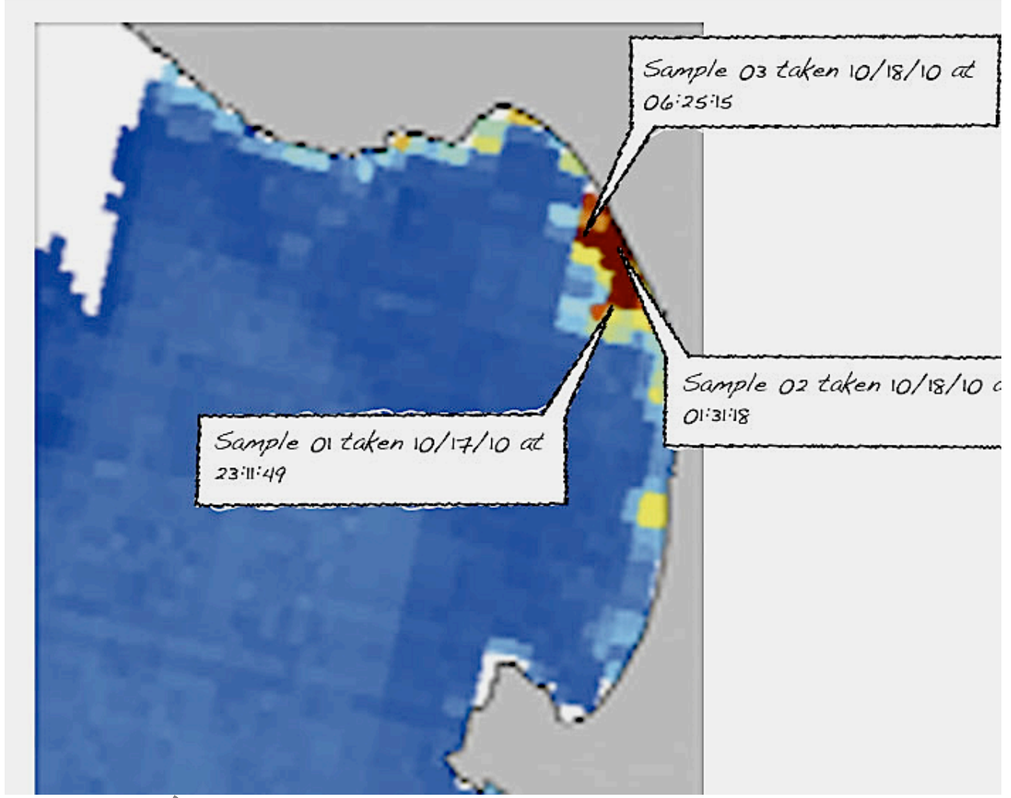
- Use of shore-based planning for coordinating multiple asset surveys and sampling
  - Temporal Constraint-based planning is an ideal vehicle for such coordination
- Sampling strategies and high-level goals are dispatched from ship/ shore to be responsive to emergent science opportunities
  - Difficult to retarget with traditional approaches
  - Abstraction will allow easier ways for command/control
  - Sampling strategies can be dynamically altered based on near real-time information
  - Dynamic task reallocation feasible in the light of failures

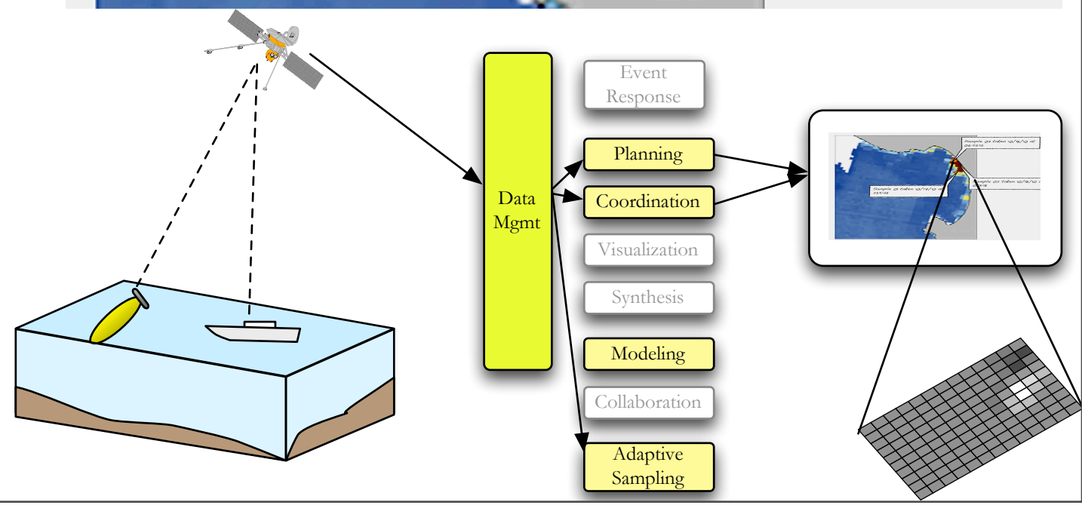




# *Planning and Inference -III: Field Reconstruction and Sampling*

- Determining where maximum information gain to target mobile assets
- Model driven autonomy a viable research goal to drive where to sample
  - bio-numerical models provide first-order approximation of coverage
  - initial efforts using advection undertaken
  - vehicles return data further assimilated into the model
- Adaptation at both individual robot and collective
  - recent work in utility based sampling undertaken
- Issues in knowledge representation
  - Bayesian approaches promising

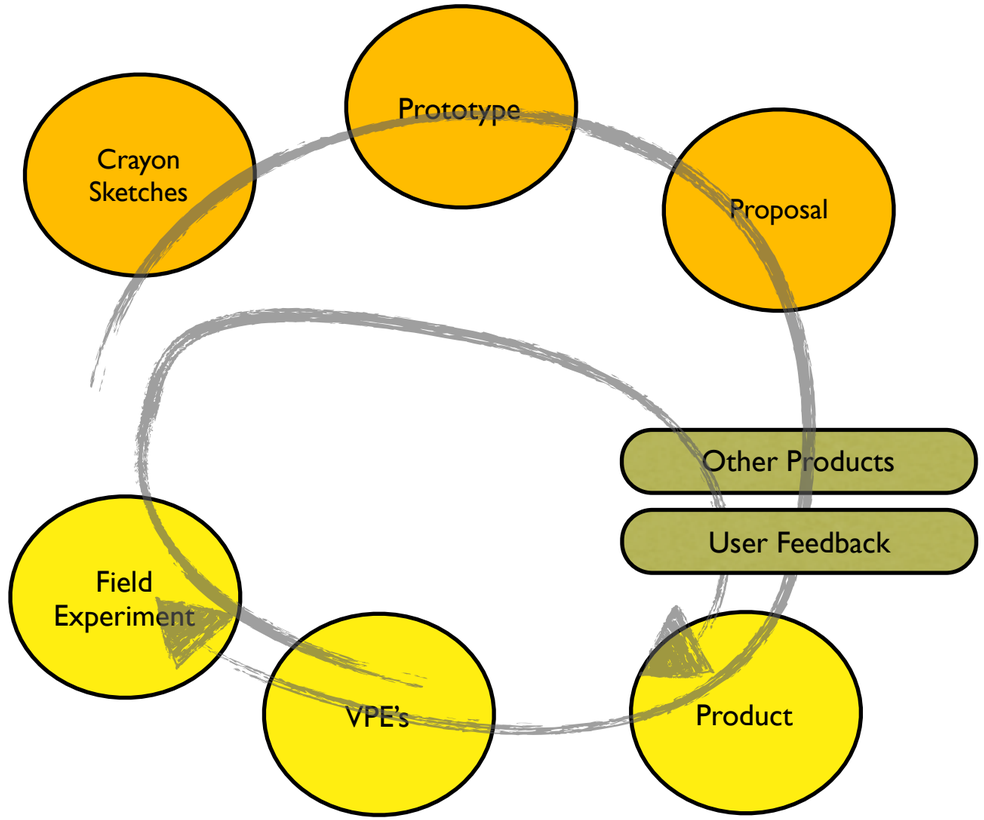


# *Development Approach*

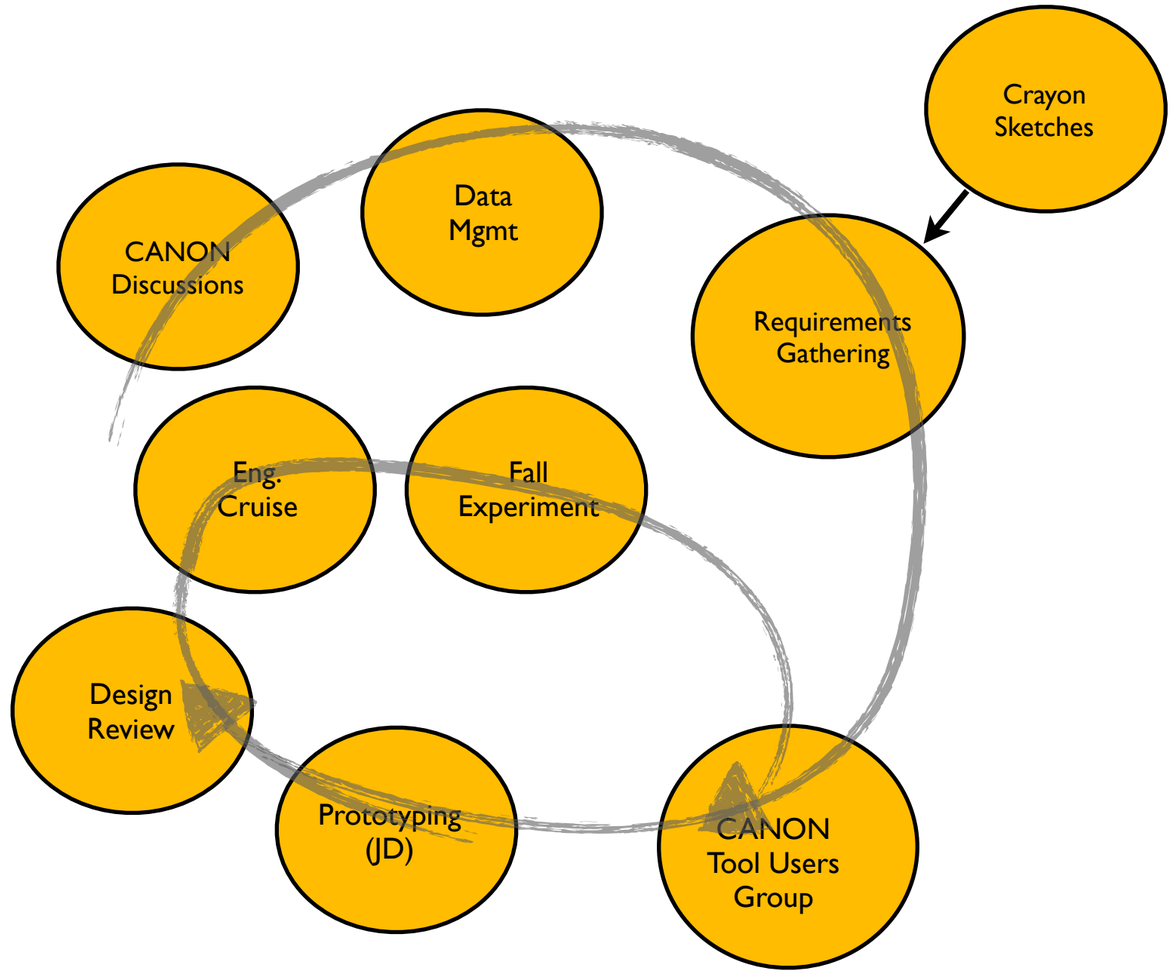
- Iterative approach to DSS design
- Extensible architecture with well defined interfaces
  - An architecture that enables **others to add value** and provide alternate implementations
  - Bindings to tools used in science
  - Documentation

- Use modern web based data visualization components and frameworks
  - Maximize user experience with rich data display, ease of use.
  - Minimize implementation and maintenance costs by leveraging modern, widely used and reasonable mature technologies



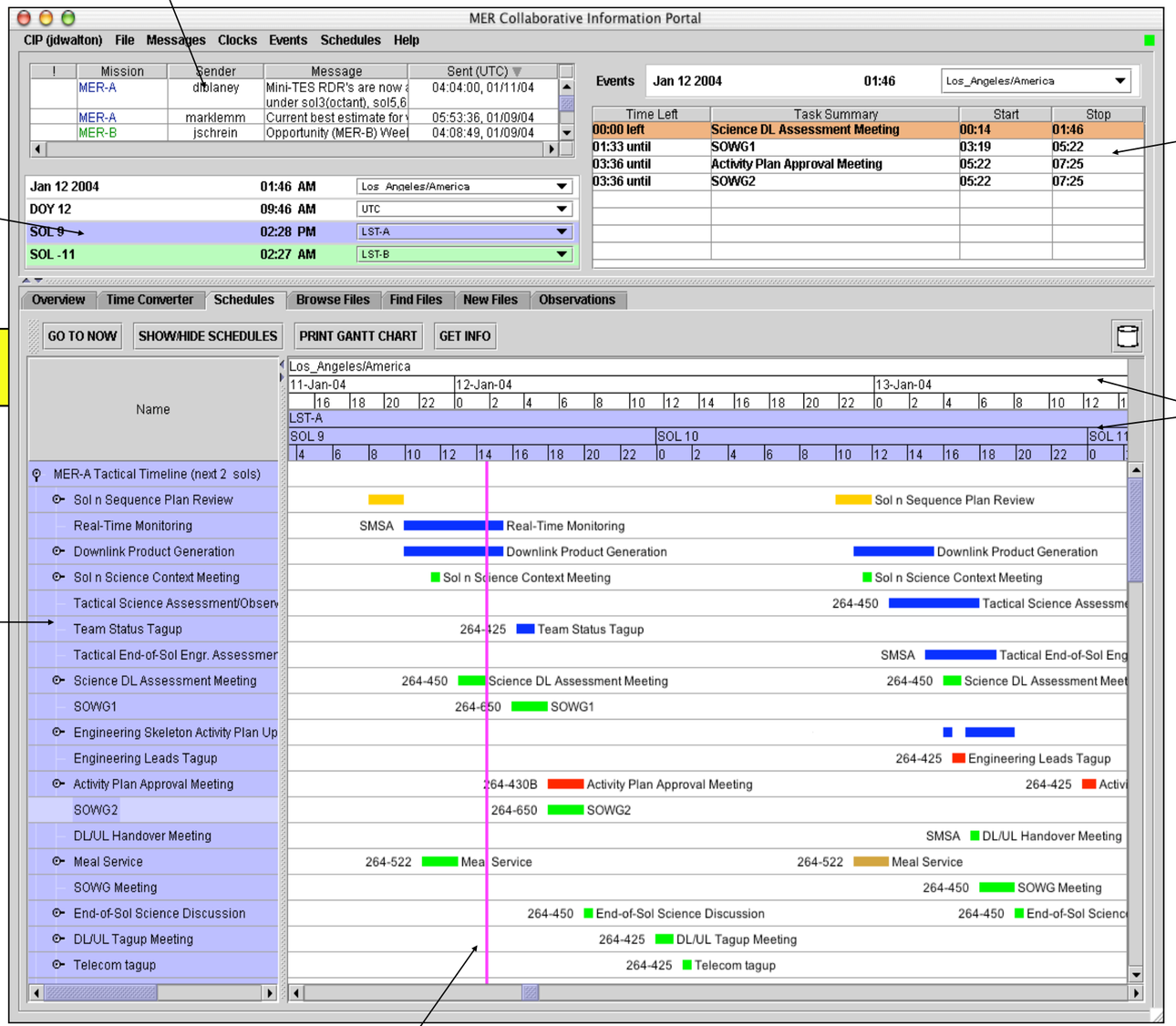
# *How did we get here?*

- CANON discussions 1Q10
- Data Management Meeting (Jan – Apr)
- Crayon Sketches (Mar – May)
  - Requirements Gathering with CANON PI's
- CANON Tools Users Group (May – ongoing)
  - Discuss techniques and technology that would be best for implementing DSS
  - Loose collaboration – Godin, Gomes, McCann, JD
- GWT Prototyping by JD (May – ongoing)
- Proposal Process 2010 (July – Sep 2010)



# Recent Relevant Tools

Broadcast announcements




Clocks

CIP **NASA Ames**

Event tracking

Timelines

Schedule viewer showing tactical event schedule

Now

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Collaborative Decision Environment
**NASA Ames**

CIP **NASA Am**

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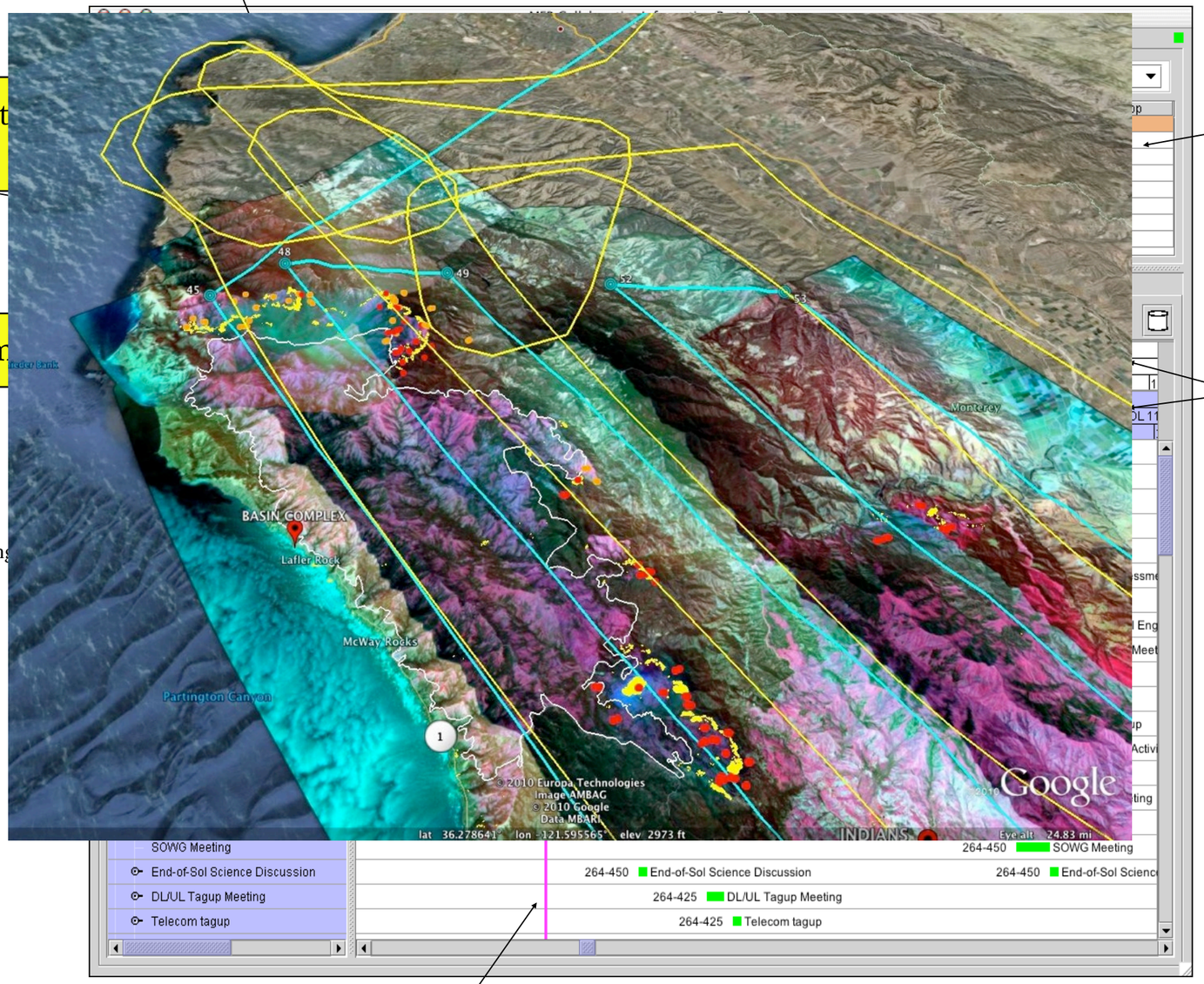

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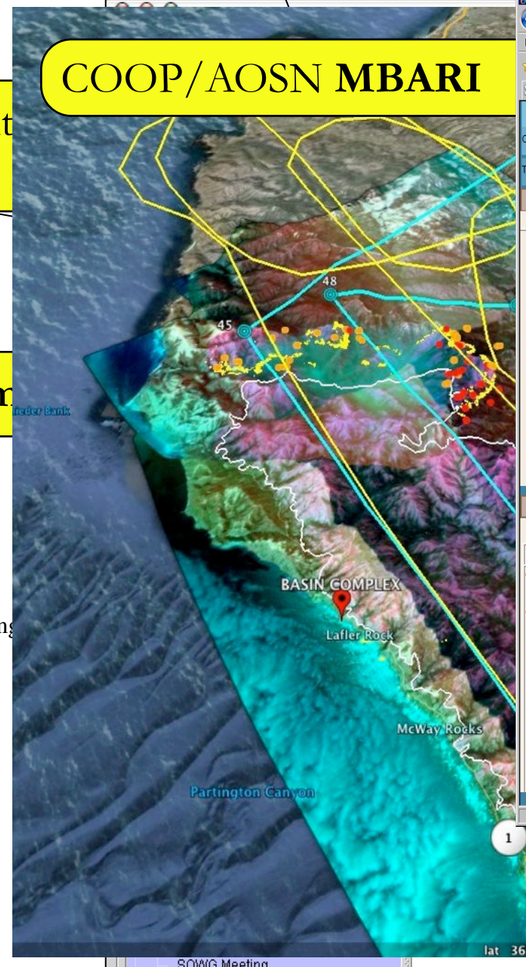


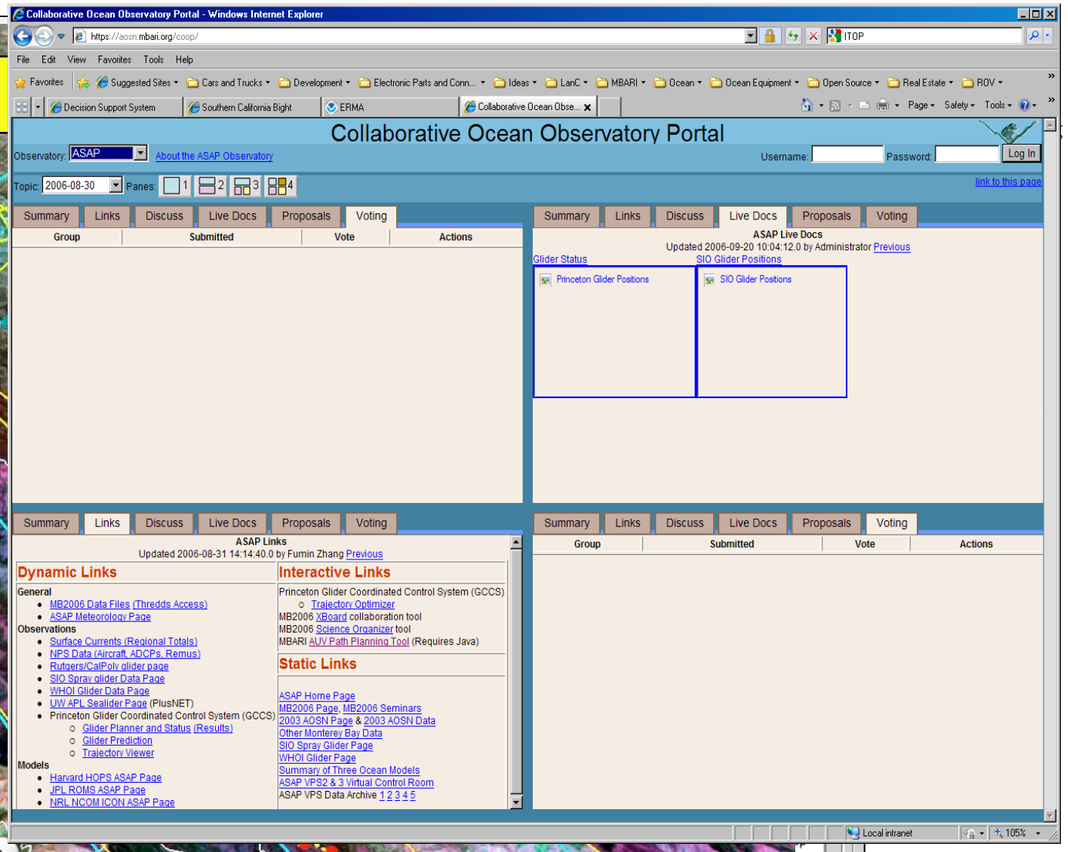


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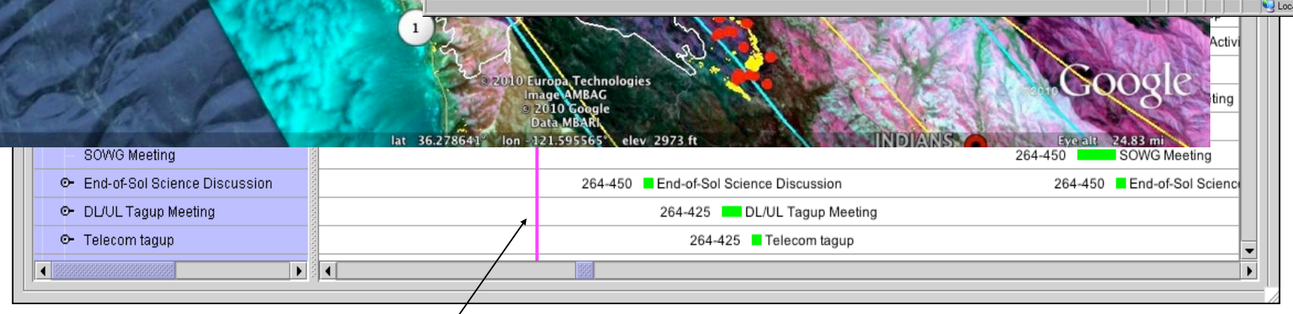


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ERMA/GoMx **NOAA**

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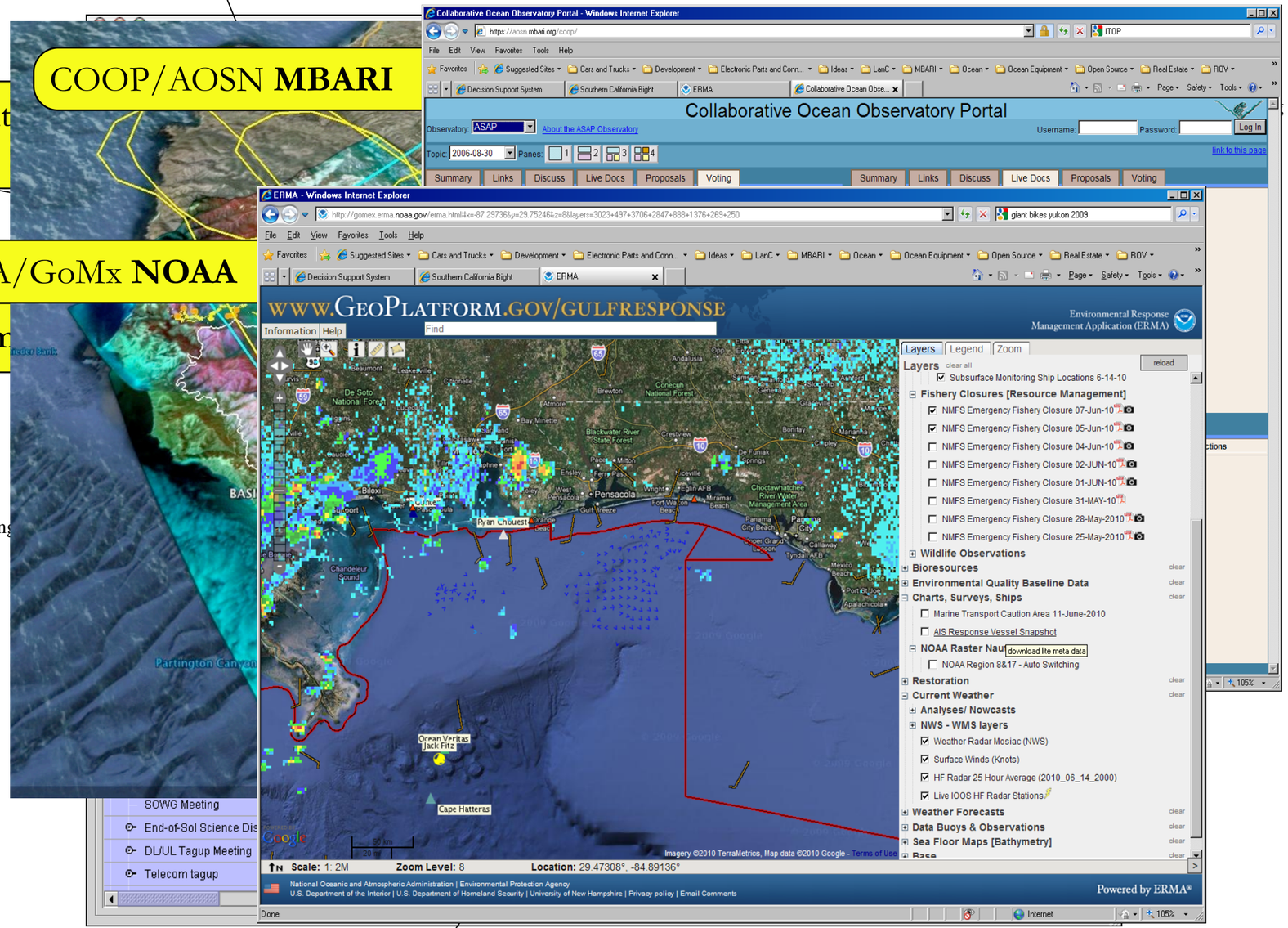


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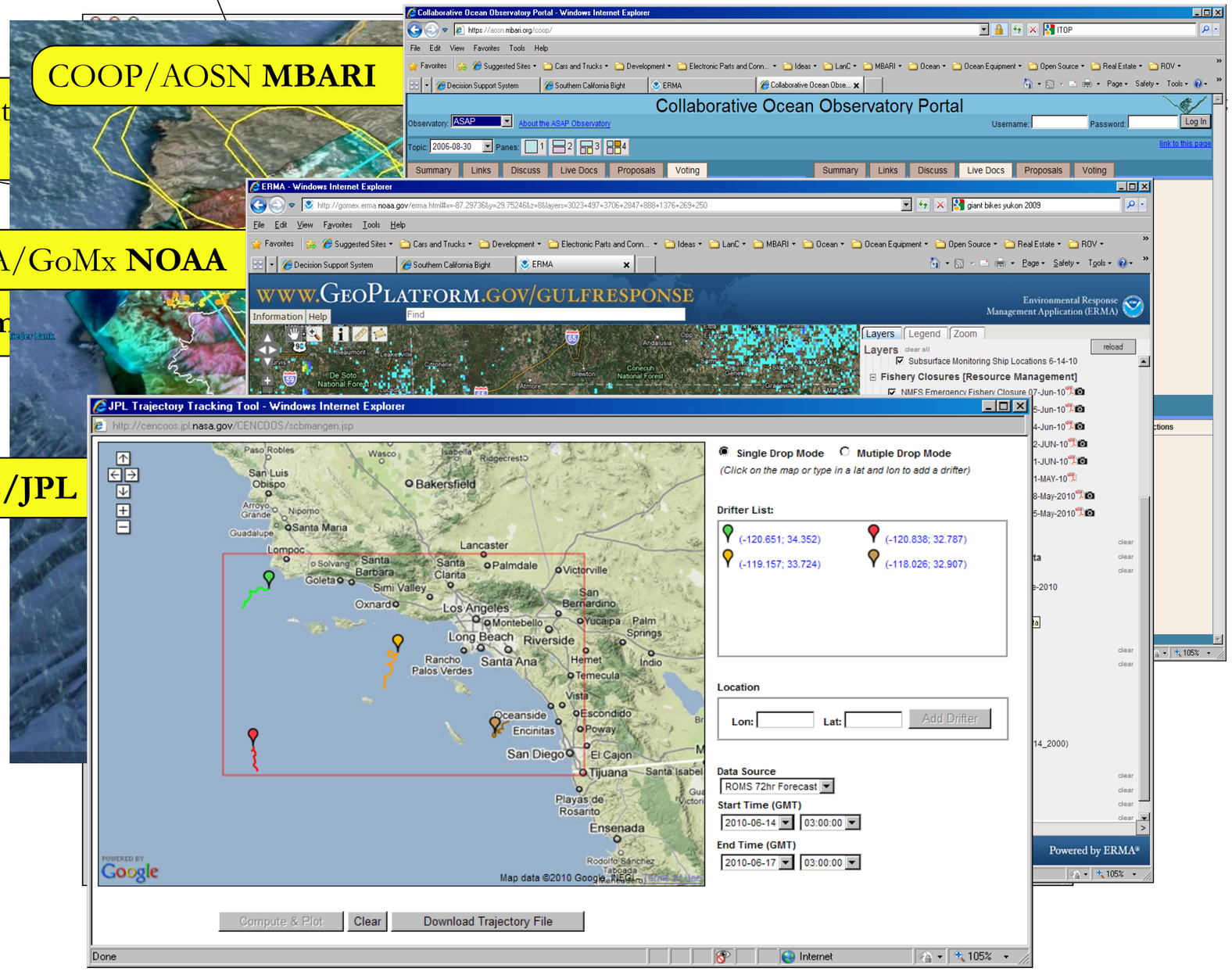
Trajectory Planning **USC/JPL**

tactical event schedule



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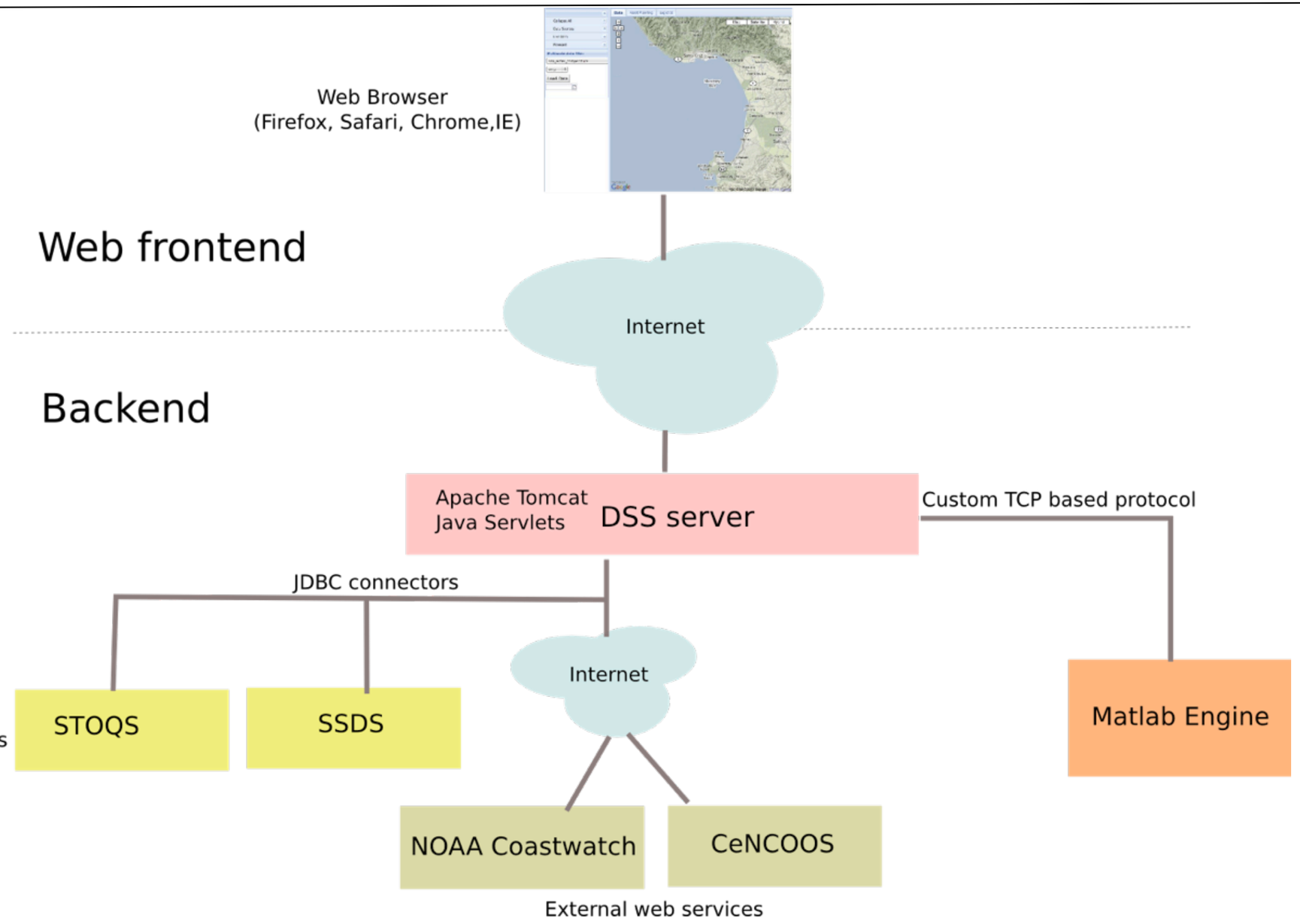
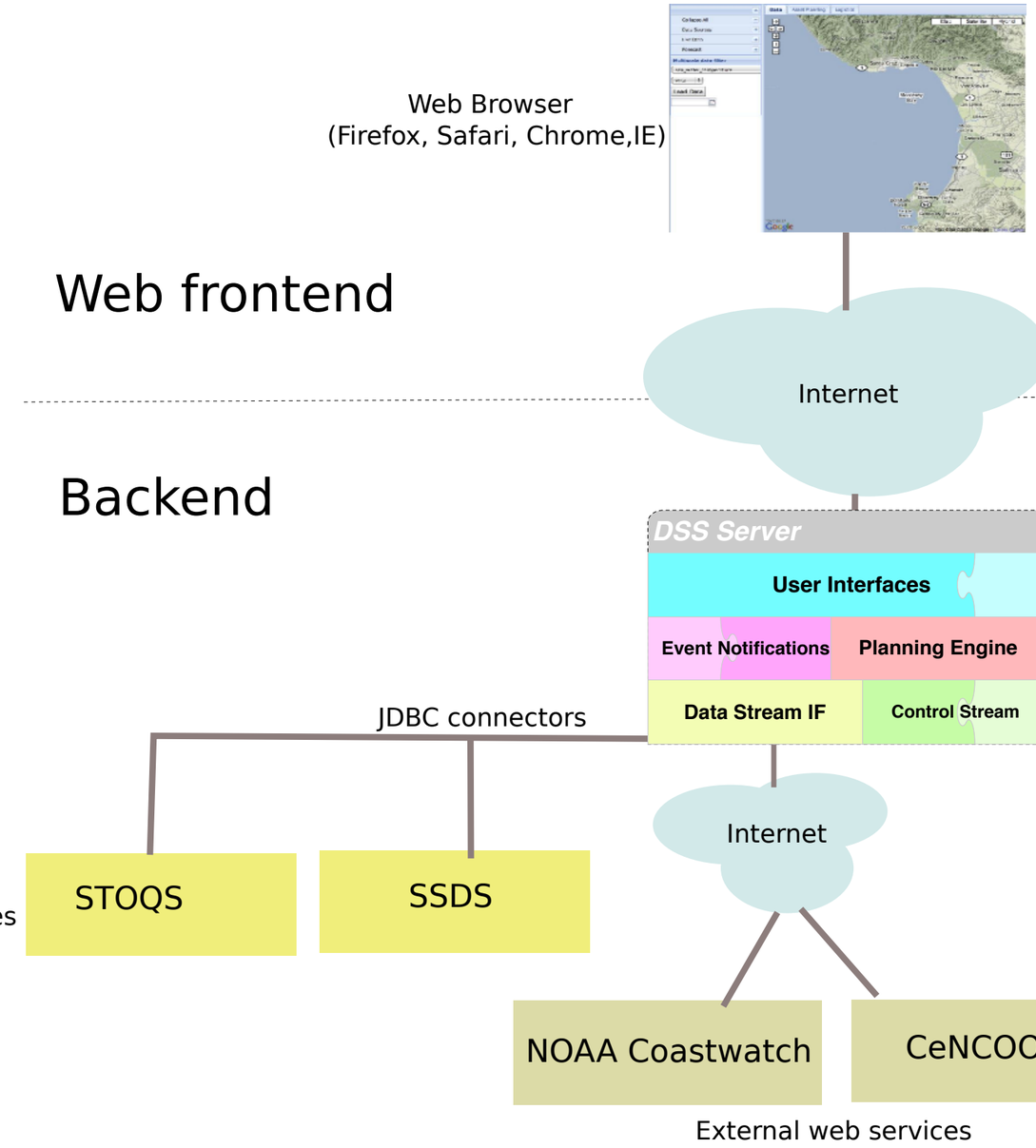


# Prototype Architectural Block Diagram



# *Prototype Architectural Block Diagram*

Web Browser
(Firefox, Safari, Chrome,IE)

- Extend work done on prototype
- Allow extensions for alternate client

- Data analysis for event detection
- Scripted at first (e.g threshold)
- Evolve toward learning

- Based on TREX engine
- Extension for MI planning
- Extension for multi-vehicle control

**User Interfaces**

**Event Notifications** | **Planning Engine**

**Data Stream IF** | **Control Stream**

JDBC

Internet

- Interface with existing MBARI tools
- May allow user to write tags

- Build a template mission for the plan
- Allow extension for 3rd party assets

Coastwatch

External web services

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(Firefox, Safari, Chr

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- Evolve toward learning

Event

Da

JDBC

Internal

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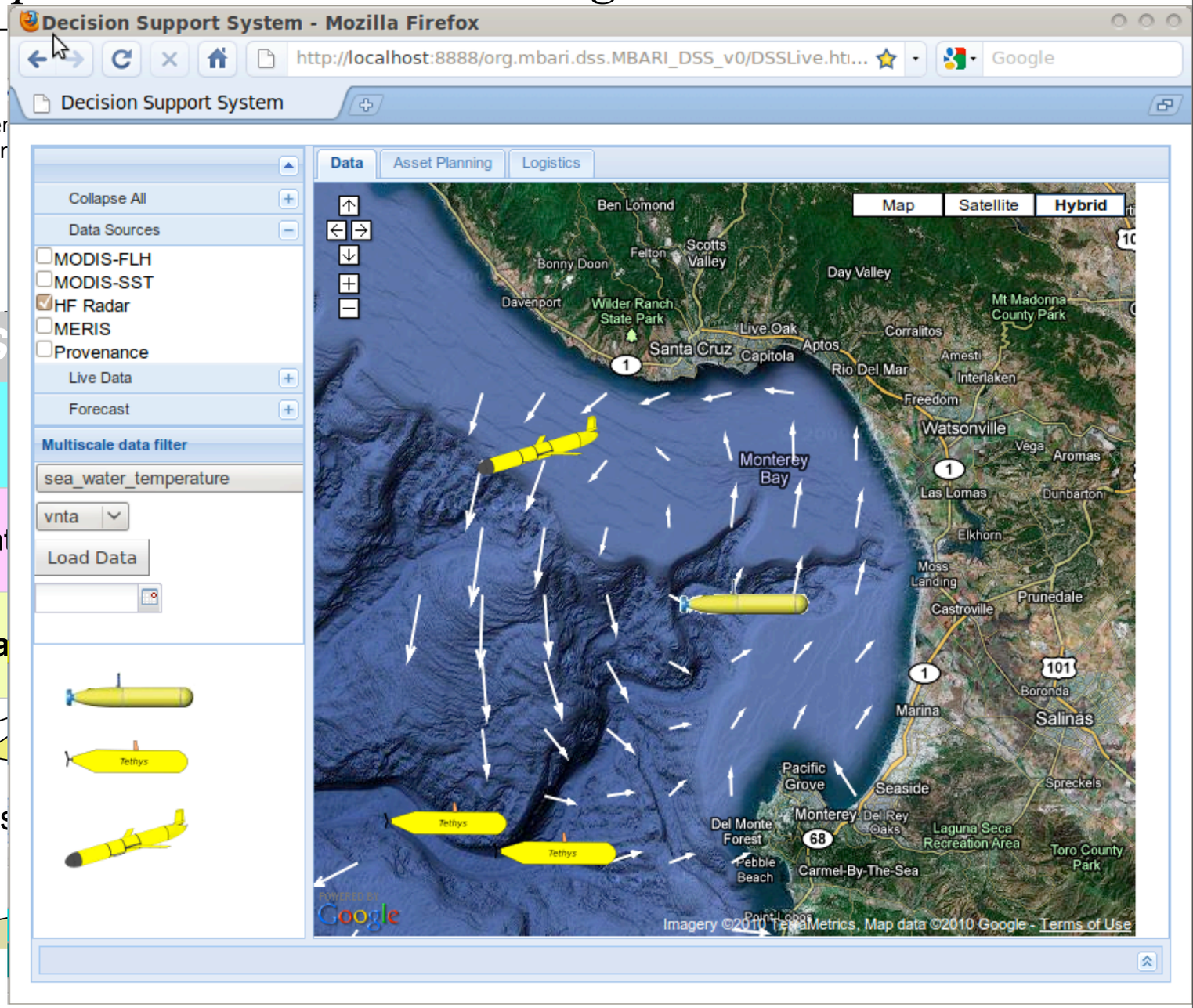
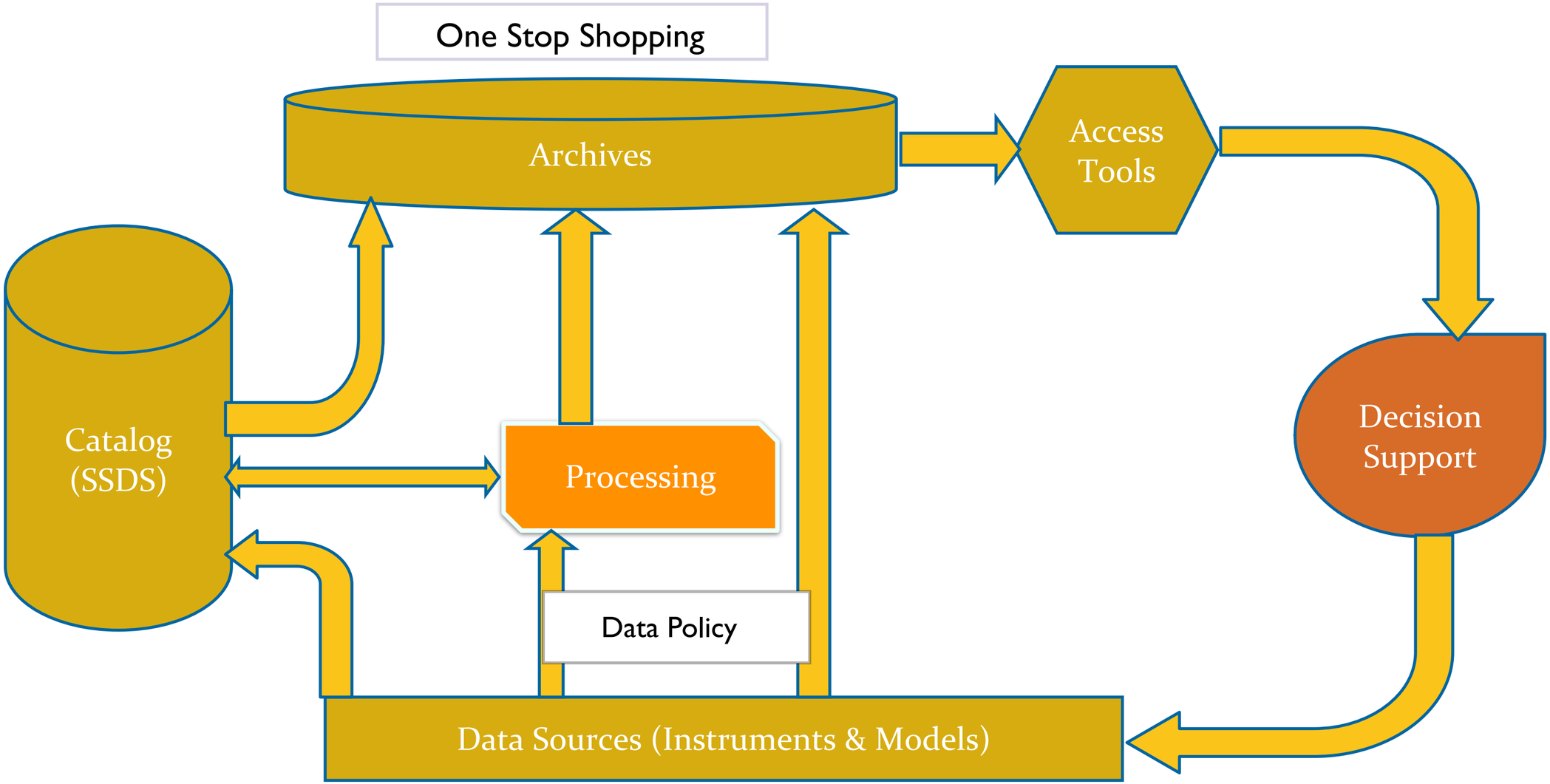


# *Dataflow amongst MBARI components*




 *Adapted from M. Godin*

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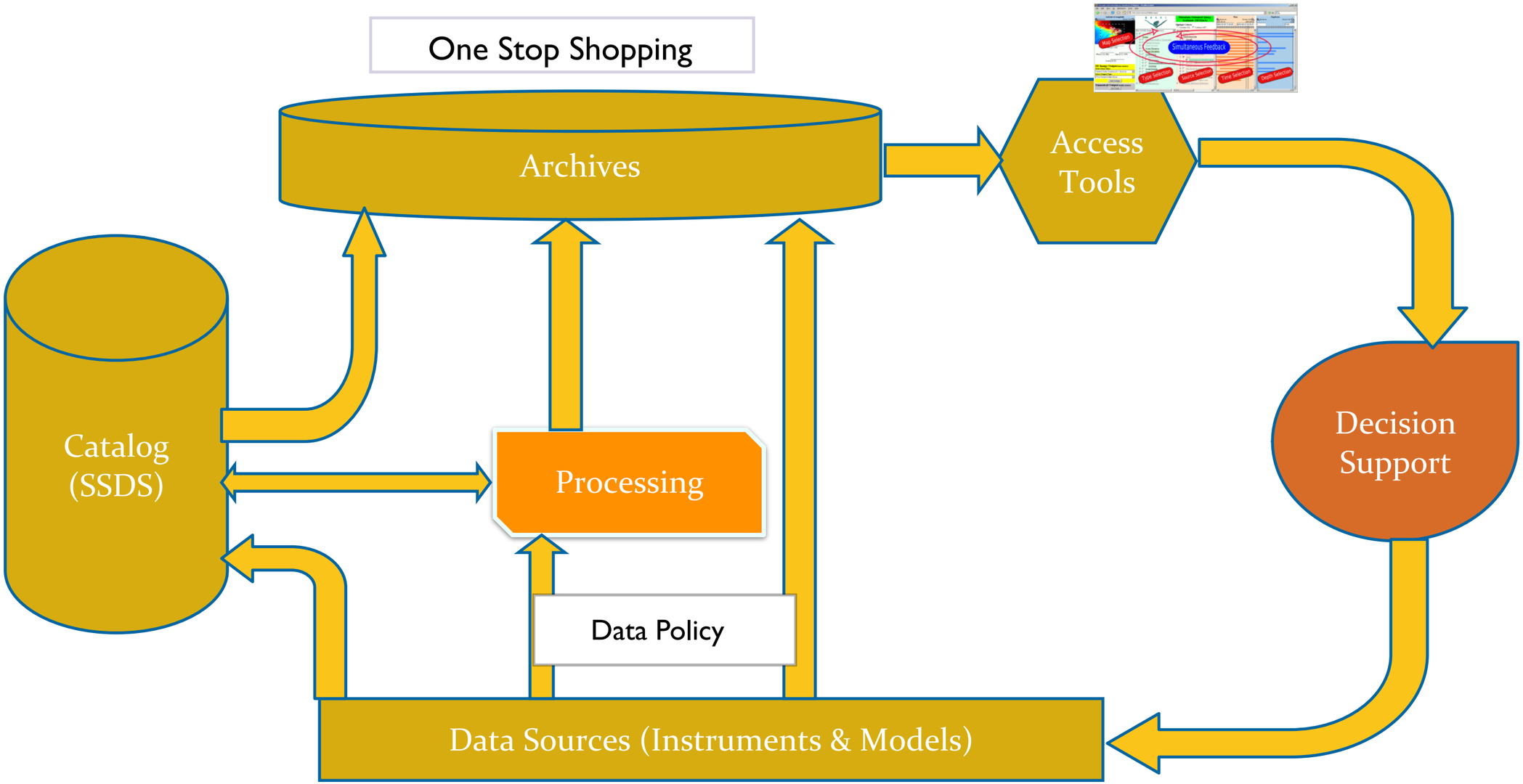


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# *Dataflow amongst MBARI components*

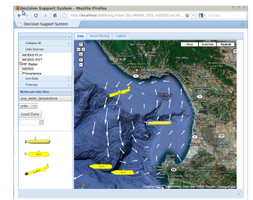
One Stop Shopping

Archives

Catalog (SSDS)

Access Tools


Visualization

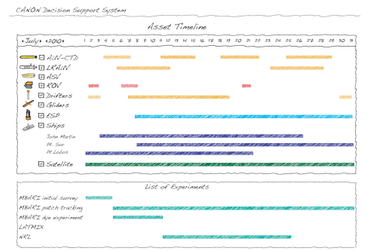


Collaboration

Decision Support

Expert Input

Planning



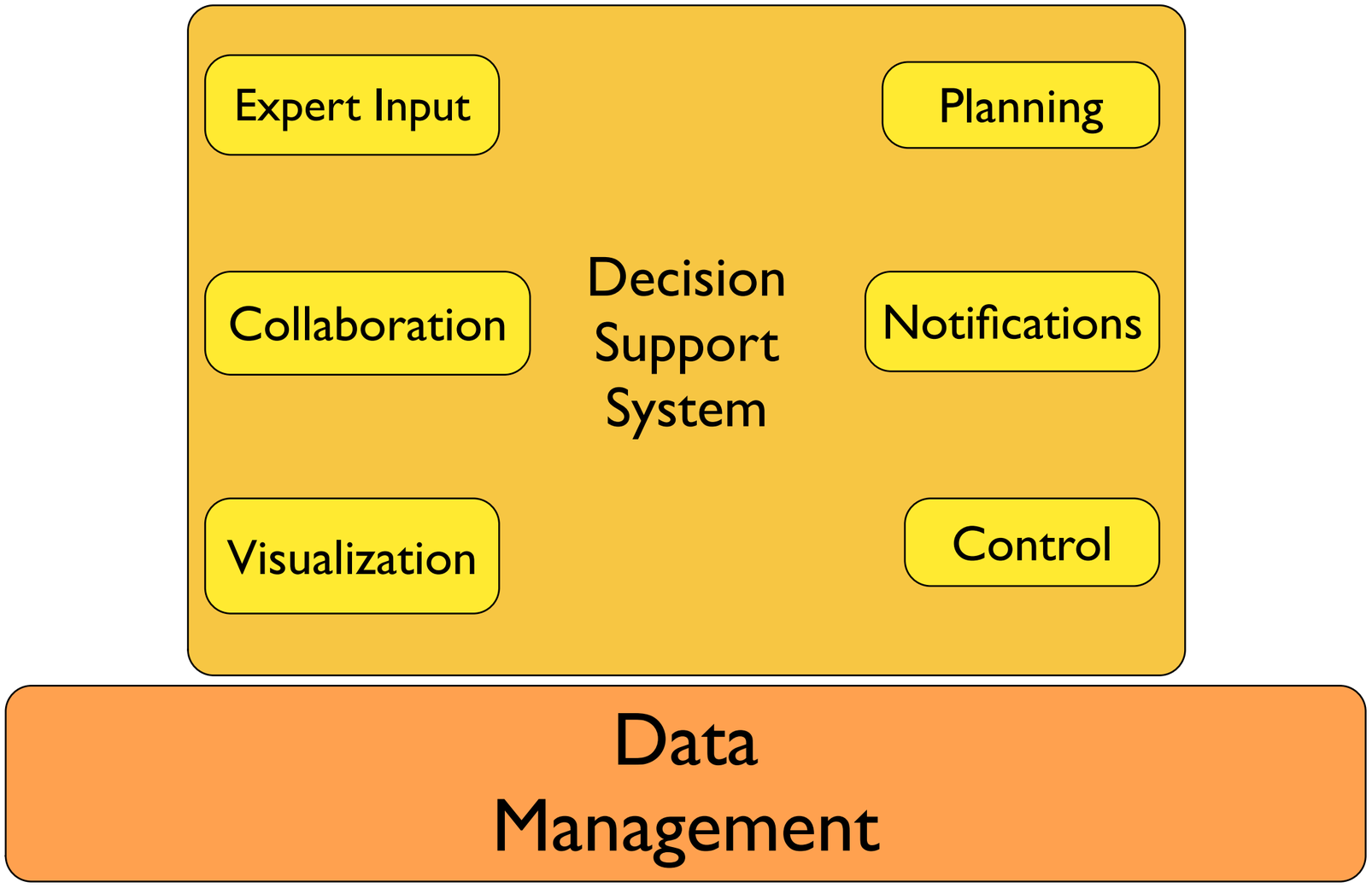

Processing

Data Policy

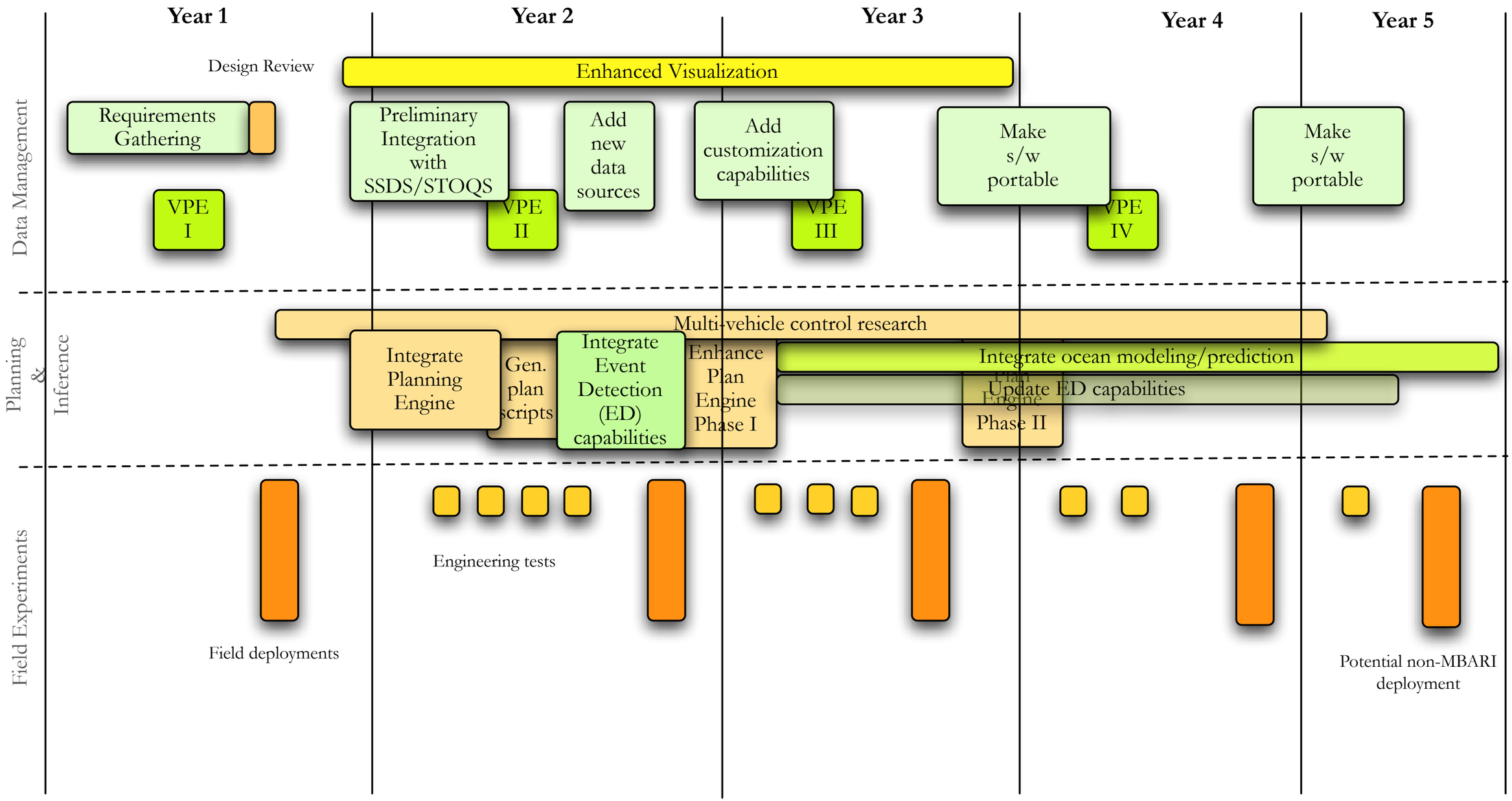
Data Sources (Instruments & Models)

 *Adapted from M. Godin*

# *Functional Block Diagram*



# *Staging DSS development*



# *Staging DSS development*

- Core Engineering effort on data integration and visualization
  - Led by Thom Maughan (Proj. Mgr)
  - Initial rapid prototyping by Jnaneshwar Das (USC Robotics)
- Core Research effort for Inference (dependent on data integration)
  - Led by Kanna Rajan (PI)
  - Frederic, JD, Rishi Graham (postdoc), other PhD students and visitors will work on research aspects
- Leverage work of McCann (One-Stop Shopping), Gomes (SSDS )and Godin (AOSN)

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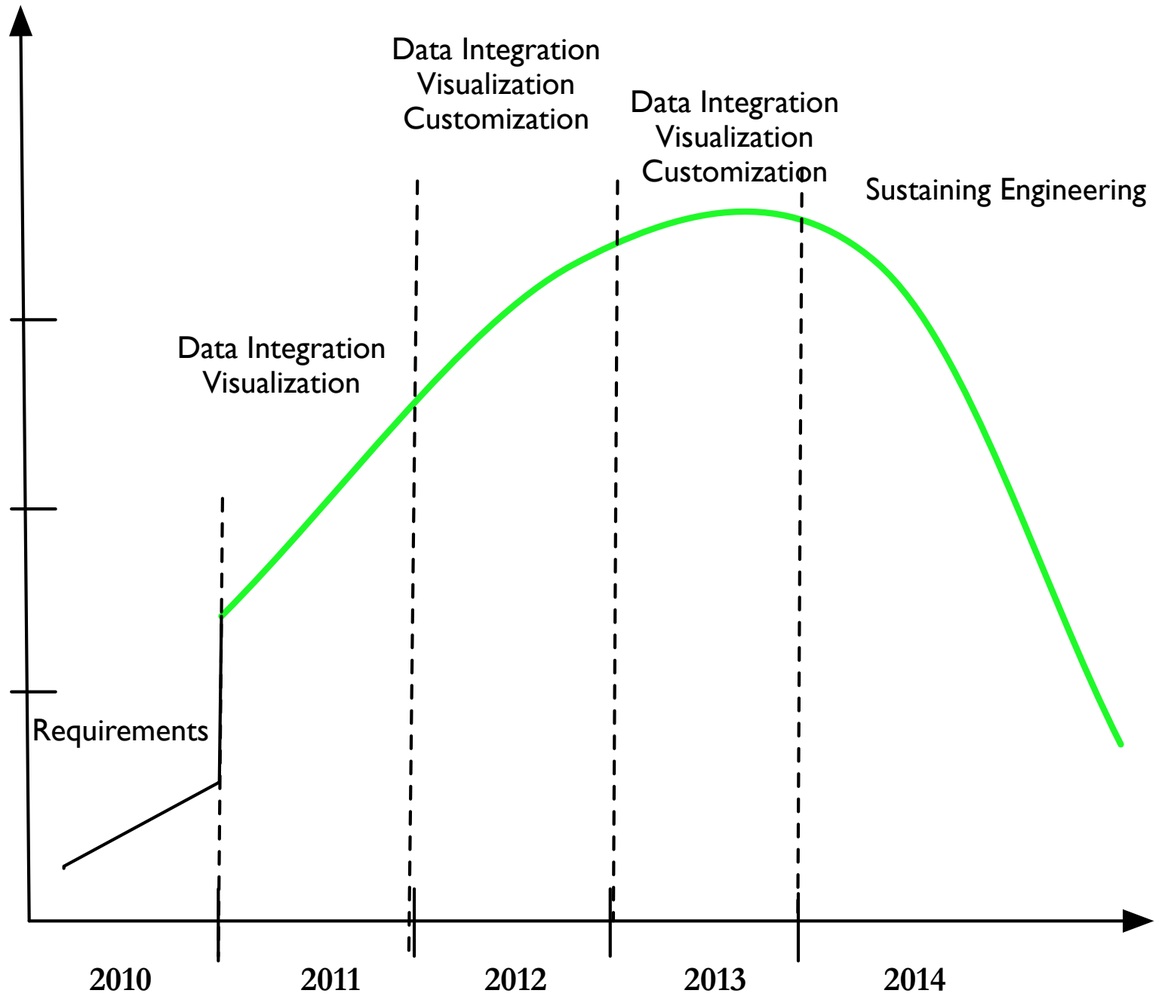
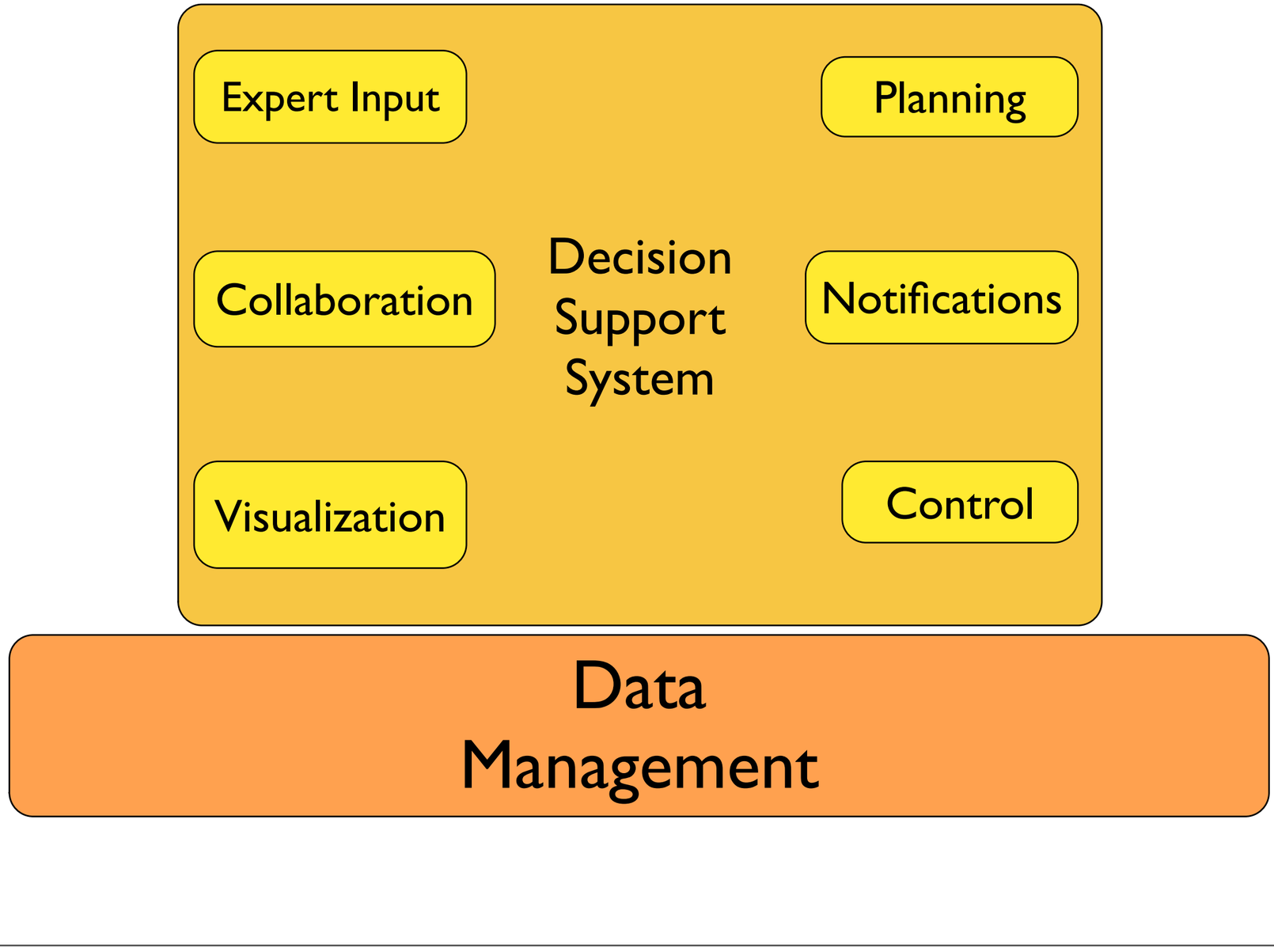


# *Resources by Function*



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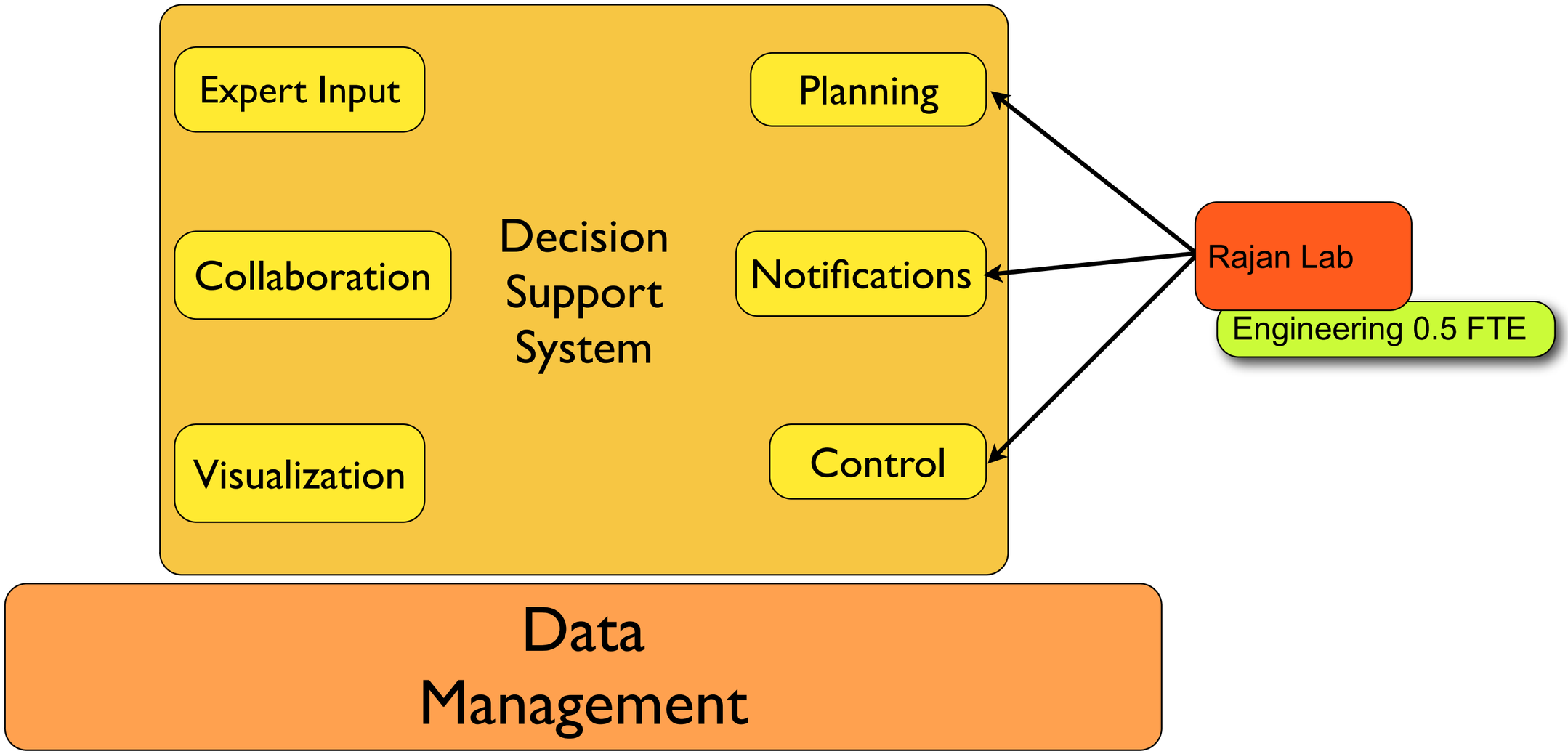

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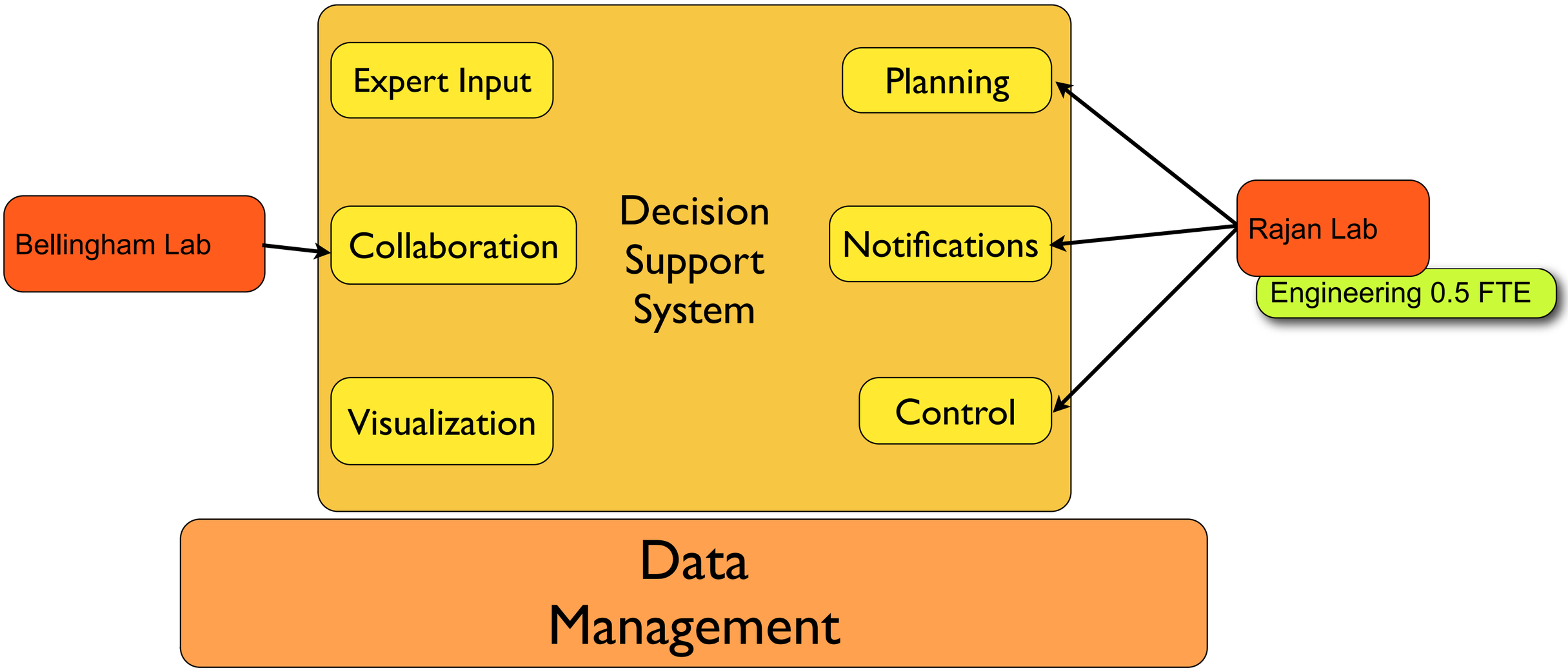

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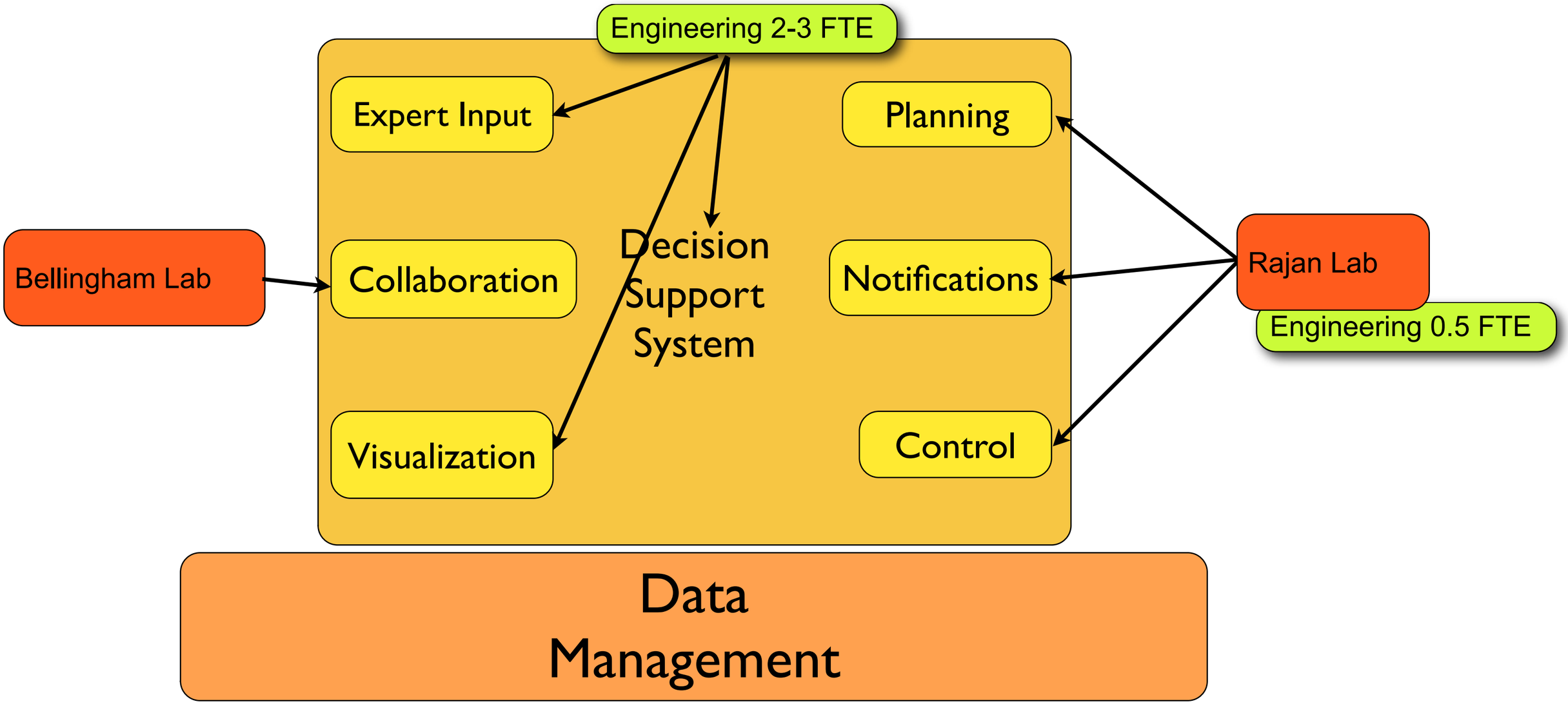

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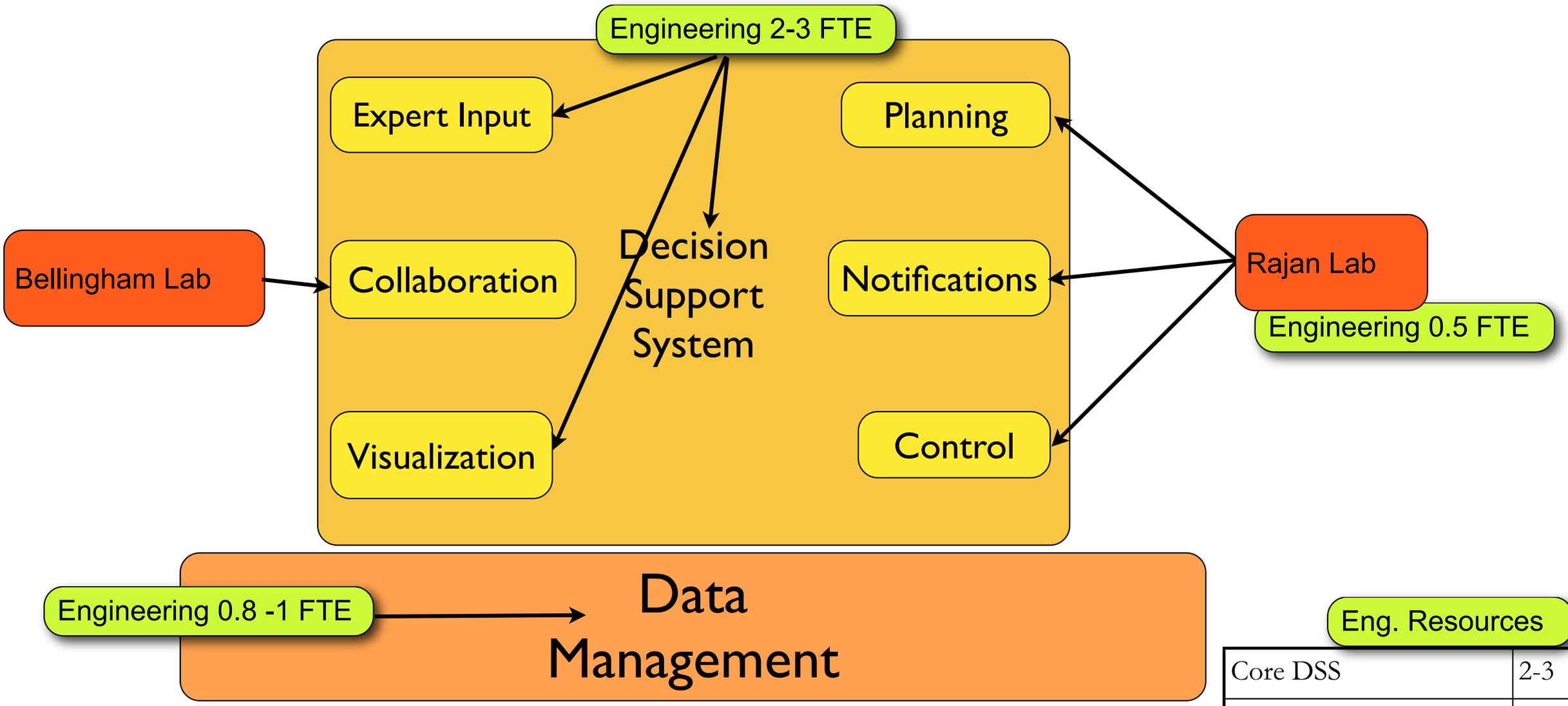


Eng. Resources

| | |
|---|---|
| Core DSS | 2-3 |
| Data Management | 0.8-1.0 |
| Planning | 0.5 |

# *Risks & Mitigations*

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- Science Requirements:
  - Science PI's as source of user requirements, may not be actual users
    - Requirements come from a wish list rather than actual needs
  - Moving "goal posts" -- rapid change in user requirements year to year
  - One size might not fit all
    - Being pulled in different directions
- Engineering issues:
  - Resources for Data Mgmt. might be spread too thin for following a more agile yearly deployment
- Balancing development/deployments/ academic research

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- Spiral Development
  - incremental changes
  - agile development methods
  - strong focus on testing
- Virtual Pilot Experiments as source of evolving user needs and feedback
- Managing priorities

**MBARI Engineering** (McCann, Gomes, Schlining)

- Data integration techniques
- Leverage SSDS, STOQS

**Jim Bellingham & Mike Godin & Yanwu**

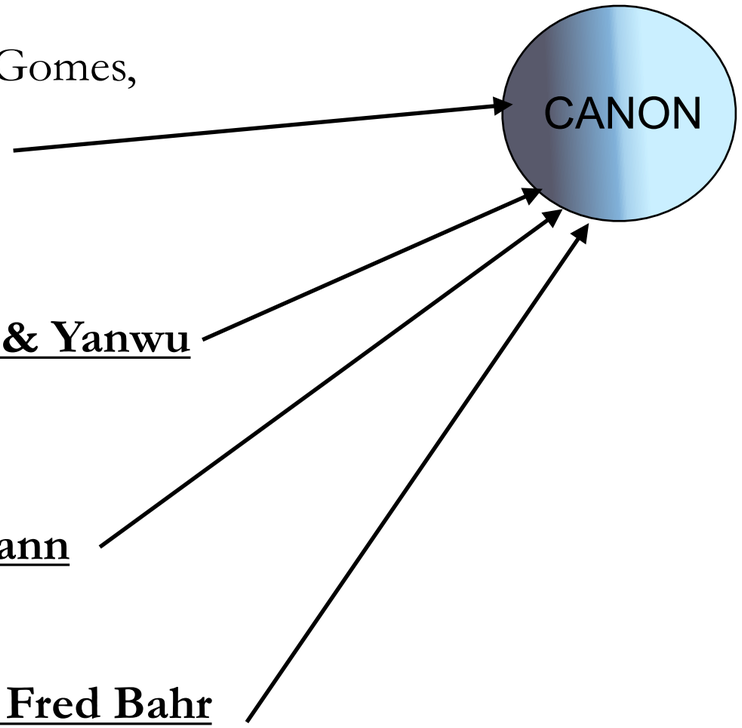
- COOP, Moqua data portals
- Sampling

**Francisco Chavez & Mike McCann**

- One-Stop shopping

**Steve Ramp & Fred Bahr**

- CenCOOS data and portal



# *Collaborators for Autonomy*

**Gabriel Elkaim**, Assoc. Prof. UCSC Computer Eng

- Students, Autonomous Surface Vessel (insured by UC/State), no liability to MBARI
- ASV potentially integrated with onboard autonomy and sampler

**MBARI Engineering** (McCann, Gomes, Schlining)

- Data integration techniques
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CANON

**Other**:

- Milind Tambe, Prof. USC AI, collaborate on Dist. Constraint Optimization research and distributed control
- Doug Horner/NPS interested in bringing 2 REMUS vehicles

**Gaurav Sukhatme**, Prof. USC Robotics

- Students, expertise in adaptive sampling, small scale marine robotics, Caron collaborator
- PhD student (JD) playing a key role in DSS and adaptive sampling
- Bringing 2-3 slocum gliders to Fall '10 field experiment

**Maria Fox**, Prof. Univ. of Strathclyde and MBARI Adjunct

- Learning models of dynamic coastal features
- Resource utilization for Planning
- Multi-vehicle planning and control

# *Concluding Remarks*

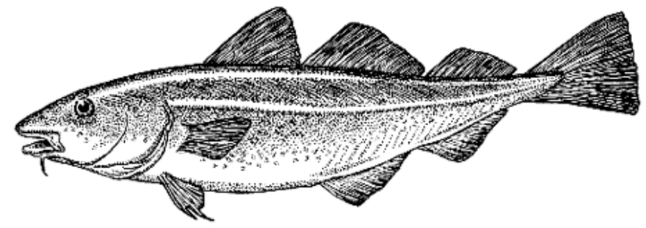
- A proposed tool for
  - pulling pieces together for oceanographic field deployments which
    - augments situational awareness
    - informs asset deployment
    - integrates data management
    - enhances collaboration
  - performing new research in automated inference and marine robotics
- A new activity to bring together disparate elements within MBARI
  - leveraging effort from participating researchers outside MBARI

Come up with a nifty name for the DSS

and

I'll buy you lunch!

Proposal #1: CoDS : Collaborative Decision Support



# *Backup Slides*

# *DSS one-on-one requirements feedback*

1. Need to obtain data from multiple sources
2. Need to be able to project a moving patch of water
3. Show near-time views from assets in the water, preferably in 3D (in case of mobile assets)
4. Provide situational awareness, planning and coordination of assets
5. Leverage existing technologies including from field experiments such as AOSN
6. Execution time retargeting of assets to be demonstrated
7. DSS will be necessary in event-response scenarios
8. Multiple users should be able to see the same “views”
9. Provide mechanism to layer different kinds of data on top of one another
10. Ability to integrate third party data products to allow customized scripts which can run and view the data differently
11. DSS components should be able to “learn” from historical data
12. Tie biological signals to where they were reported from in-situ within the water-column
13. Need to show vehicle track to know the context and where the vehicle has been and is going
14. Need to structure development in a phased manner and to capture evolving science requirements

# *DSS one-on-one requirements feedback*

15. Need a mission planning tool with history; what was planned and what actually happened
16. Assets should have the capability to be re-targeted in-situ (including ESP) via shore side
17. Consider a way in which data analysis can be uploaded based on shore-side analysis and patches of water are annotated
18. Shore-side planning to augment where and what a platform could do
19. Have a discussion board to record comments/opinions to make discussions asynchronous
20. Need a voting capability to decide on multiple future course of actions
21. Consider how resources and costs can be recorded for a course of future action
22. Visualizations should have annotations which can be shared or stored privately
23. Need a mission planning view which shows how assets are distributed and/or available for a field program
24. Design DSS to be exportable outside MBARI
25. Can anything be learned from how the Metrology community uses such tools?