Integrating Geographical Information Systems and Grid Services for Earthquake Forecasting

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A Big Picture for SERVOGrid

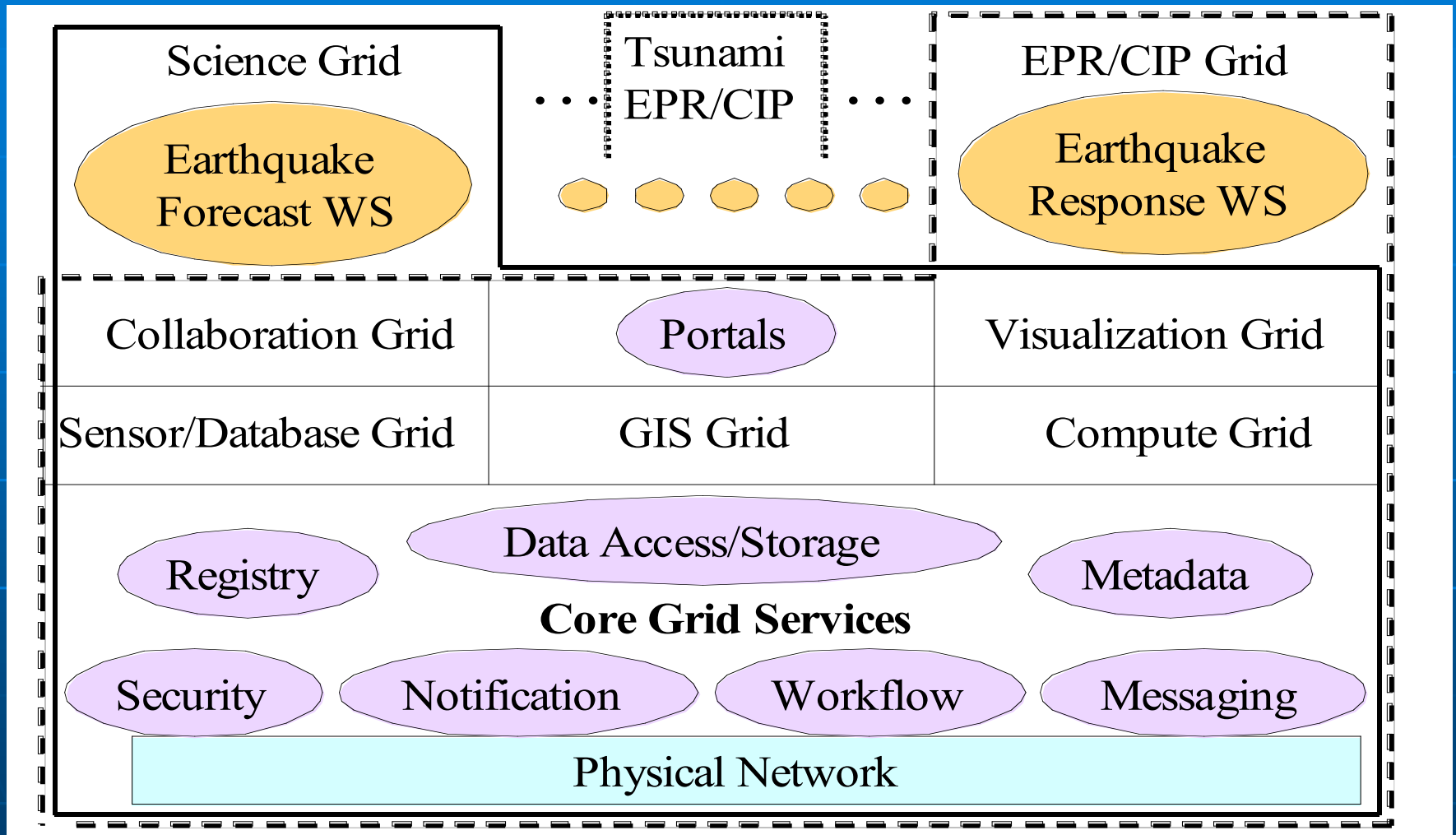


Figure 1: Science , Critical Infrastructure Protection (CIP) and Emergency Preparedness and Response (EPR) Grids built as a Grid of Web Service (WS) Grids

The Problem: Integrating Data, Applications, and Client Devices

- The key issue we try to solve is building the distributed computing infrastructure that can connect
  - Legacy data archives
  - Executable codes
  - Real time data sources
  - Collaboration services (http://www.globalmmcs.org)
  - Client tools for collaboration
    - Audio/Video systems, whiteboard annotators, etc
- Various application-specific grids can be built out of the common infrastructure
  - Science Grids (described here)
  - Emergency planning, crisis response
- We choose certain fixed points for our foundations
  - Web Service standards: SOAP and WSDL
  - Other standards where available: GIS standards
  - Universal messaging substrate for SOAP and other messages: http://www.naradabrokering

SERVO Apps and Their Data

- As summarized below, many SERVO codes use observational data measurements as input and create geo-located results.
- GeoFEST: Three-dimensional viscoelastic finite element model for calculating nodal displacements and tractions. Allows for realistic fault geometry and characteristics, material properties, and body forces.
  - Relies upon fault models with geometric and material properties.
- Virtual California: Program to simulate interactions between vertical strike-slip faults using an elastic layer over a viscoelastic half-space.
  - Relies upon fault and fault friction models.
- Pattern Informatics: Calculates regions of enhanced probability for future seismic activity based on the seismic record of the region
  - Uses seismic data archives
- RDAHMM: Time series analysis program based on Hidden Markov Modeling. Produces feature vectors and probabilities for transitioning from one class to another.
  - Used to analyze GPS and seismic catalog archives.
  - Can be adapted to detect state change events in real time.

Geographical Information System Services as Data Grid Components

- We decided that the Data Grid components of SERVO are best implemented using standard GIS services.
  - Use Open Geospatial Consortium standards
  - Maximize reusability in future SERVO projects
  - Provide downloadable GIS software to the community as a side effect of SERVO research.
- We implemented two cornerstone standards
  - Web Feature Service (WFS): data service for storing abstract map features
    - Supports queries
    - Faults, GPS, seismic records
  - Web Map Service (WMS): generate interactive maps from WFS's and other WMS's.
    - Maps are overlays: we grab images from OnEarth, overlay our additional images generated from features.
    - Can also extract features (faults, seismic events, etc) from user GUIs to drive problems such as the PI code and (in near future) GeoFEST, VC.
- We have also recently completed initial GPS Sensor Grid services

Building the GIS Grid

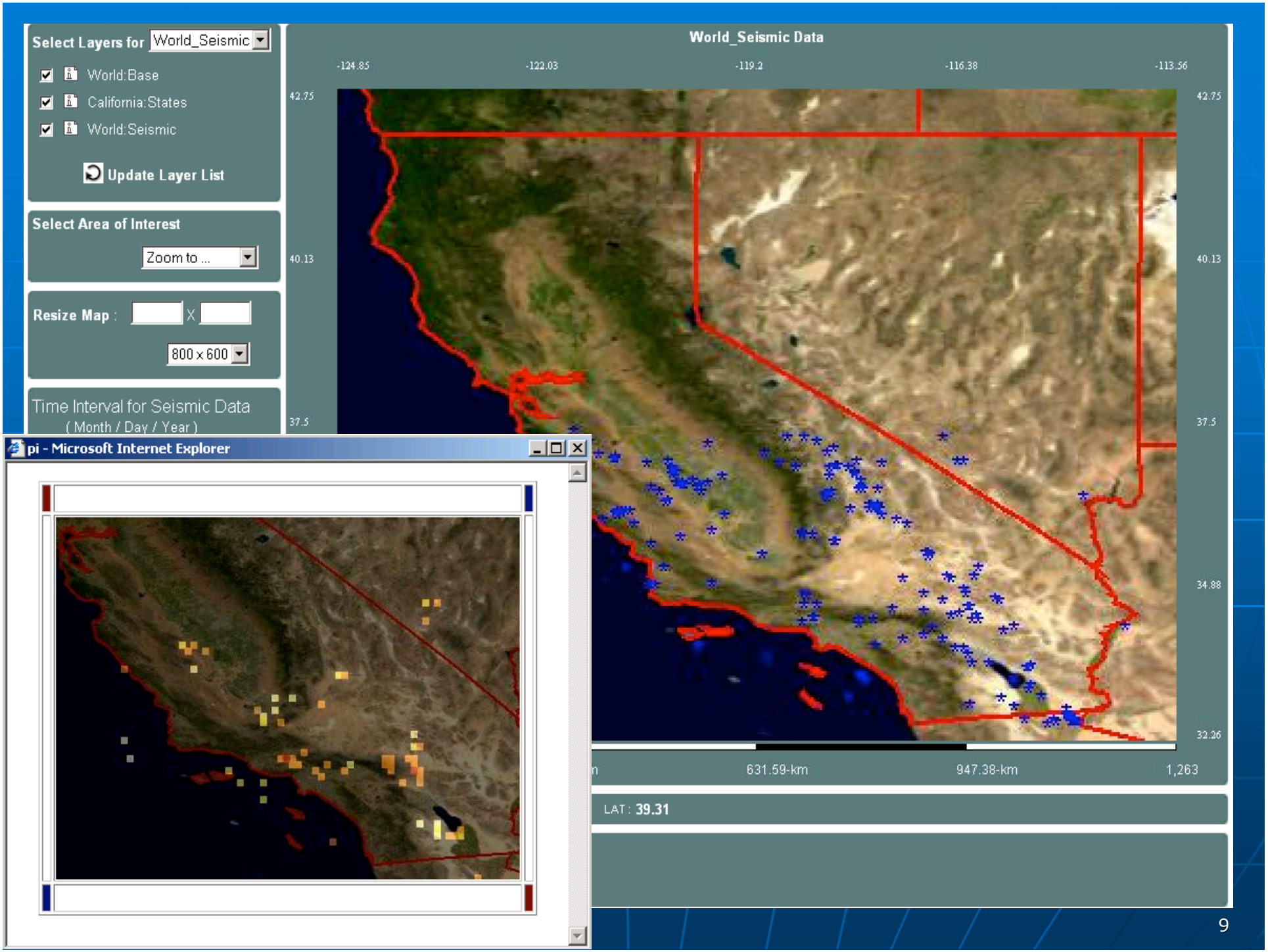
- We built these as Web Services
  - "WS-I+" style Grid
  - WSDL and SOAP: programming interfaces and messaging formats
  - You can work with the data and map services through programming APIs as well as browser interfaces.
  - Running demos and downloadable code are available from www.crisisgrid.org.
- Recent/ongoing work
  - Improved WFS performance
  - Integrating WMS clients with more applications
  - WMS clients publicly available and downloadable (as portlets).
  - Implementing WMS as a streaming video server.
  - Implementing SensorML for streaming, real-time data.

Pattern Informatics (PI)

- **PI is a technique developed at University of California, Davis for analyzing earthquake seismic records to forecast regions with high future seismic activity.**
  - **They have correctly forecasted the locations of 15 of last 16 earthquakes with magnitude > 5.0 in California.**
- **See Tiampo, K. F., Rundle, J. B., McGinnis, S. A., & Klein, W. Pattern dynamics and forecast methods in seismically active regions. *Pure Ap. Geophys.* 159, 2429-2467 (2002).**
  - **http://citebase.eprints.org/cgi-bin/fulltext?format=application/pdf&identifier=oai%3AarXiv.org%3Acond-mat%2F0102032**
- **PI is being applied other regions of the world, and John has gotten a lot of press.**
  - **Google "John Rundle UC Davis Pattern Informatics"**

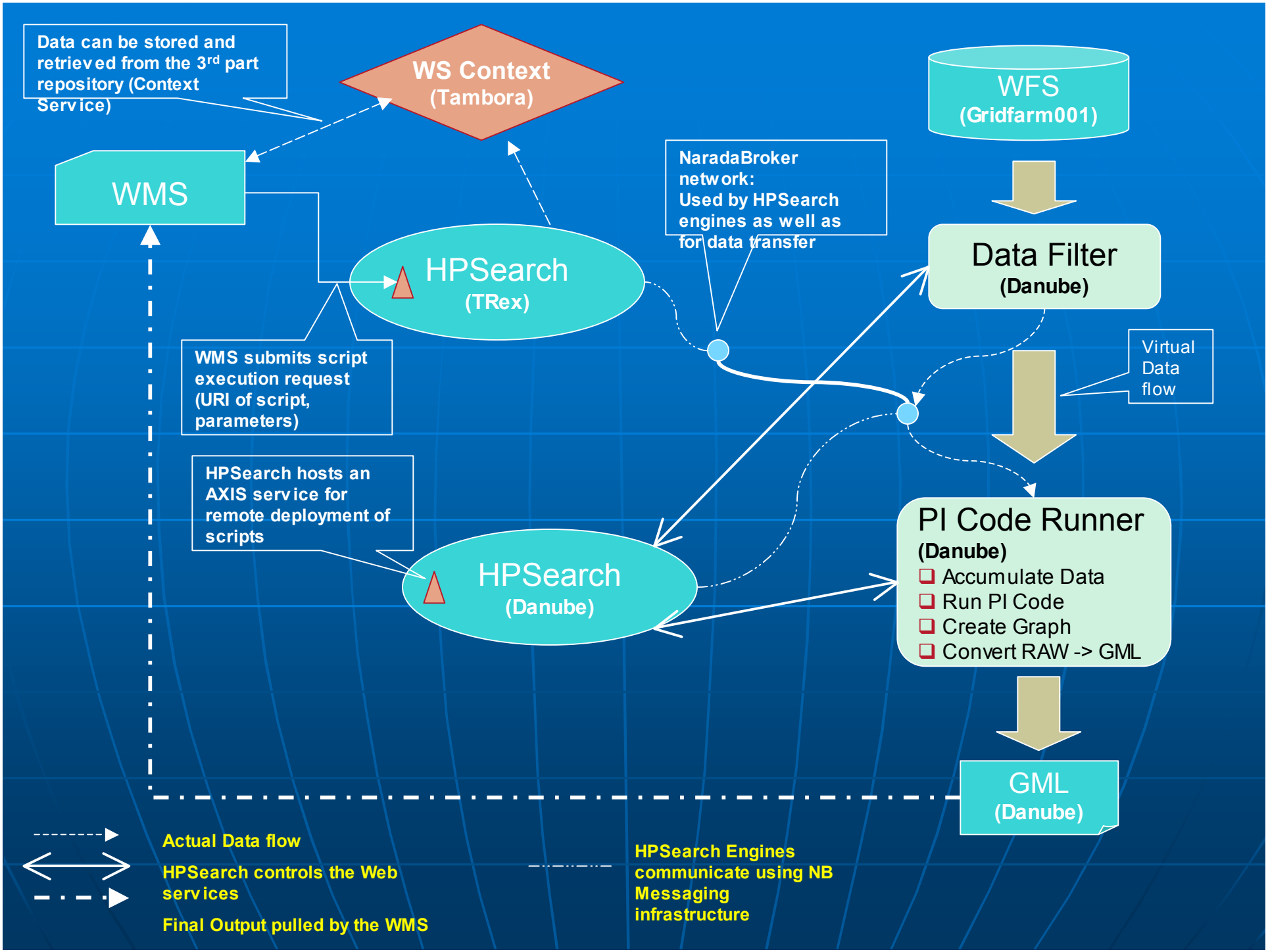
Pattern Informatics in a Grid Environment

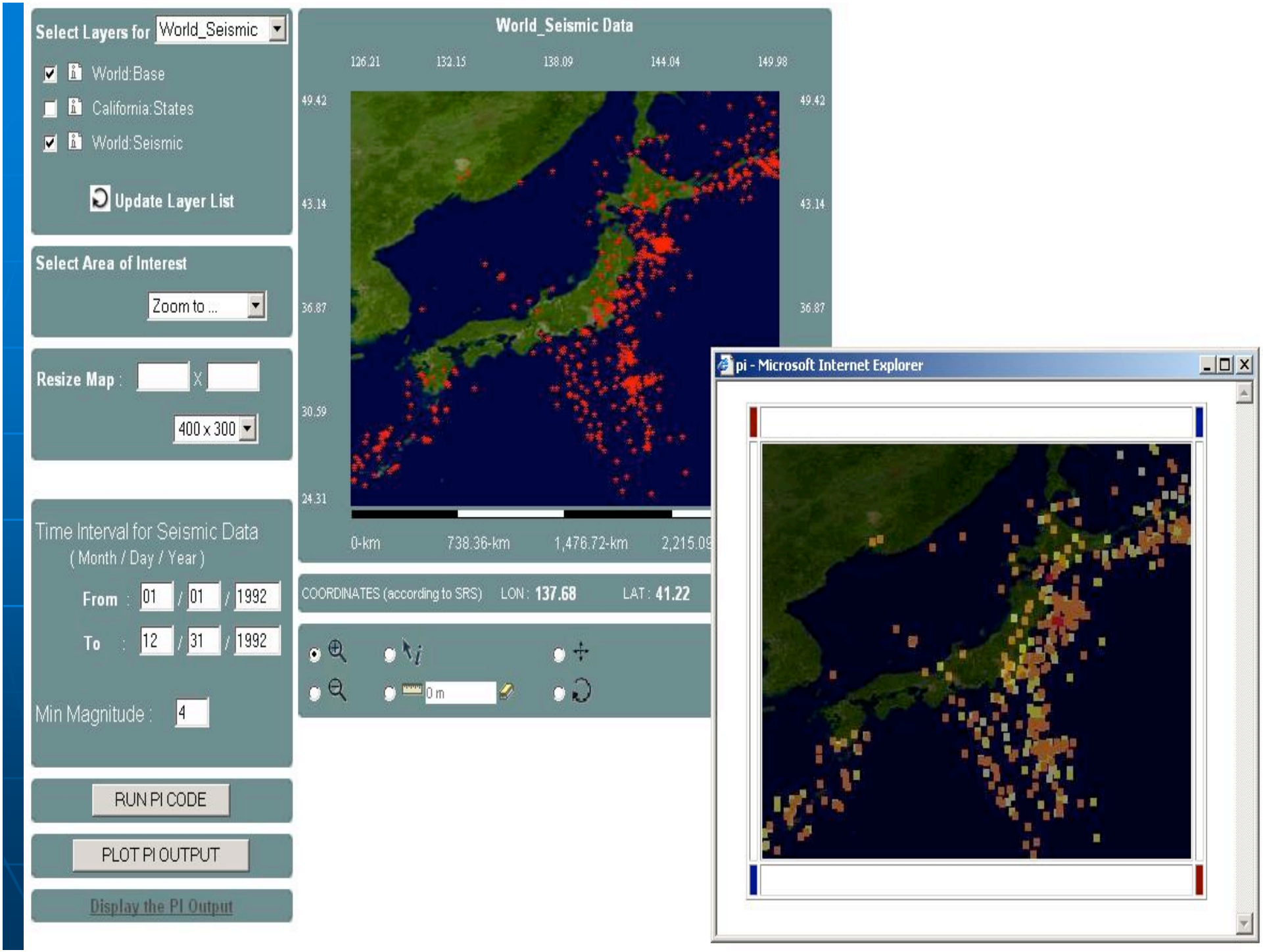
- **PI in a Grid environment:**
  - Hotspot forecasts are made using publicly available seismic records.
    - Southern California Earthquake Data Center
    - Advanced National Seismic System (ANSS) catalogs
  - Code location is unimportant, can be a service through remote execution
  - Results need to be stored, shared, modified
  - Grid/Web Services can provide these capabilities
- **Problems:**
  - How do we provide programming interfaces (not just user interfaces) to the above catalogs?
  - How do we connect remote data sources directly to the PI code.
  - How do we automate this for the entire planet?
- **Solutions:**
  - Use GIS services to provide the input data, plot the output data
    - WFS for data archives, WMS for generating maps
  - Use HPSearch tool to tie together and manage the distributed data sources and code.


Select Layers for World_Seismic
World:Base
California:States
World:Seismic
Update Layer List
Select Area of Interest
Zoom to ...
Resize Map :
X
800 x 600
Time Interval for Seismic Data
(Month / Day / Year)
World_Seismic Data
-124.85
-122.03
-119.2
-116.38
-113.56
42.75
40.13
37.5
34.88
32.26
631.59-km
947.38-km
1,263
LAT : 39.31
pi - Microsoft Internet Explorer

Tying It All Together: HPSearch

- **HPSearch is an engine for orchestrating distributed Web Service interactions**
  - **It uses an event system and supports both file transfers and data streams.**
  - **Legacy name**
- **HPSearch flows can be scripted with JavaScript**
  - **HPSearch engine binds the flow to a particular set of remote services and executes the script.**
- **HPSearch engines are Web Services, can be distributed interoperate for load balancing.**
  - **Boss/Worker model**
- **ProxyWebService: a wrapper class that adds notification and streaming support to a Web Service.**


Data can be stored and retrieved from the 3rd part repository (Context Service)
WS Context (Tambora)
WFS (Gridfarm001)
WMS
NaradaBroker network: Used by HPSearch engines as well as for data transfer
HPSearch (TRex)
Data Filter (Danube)
WMS submits script execution request (URI of script, parameters)
Virtual Data flow
HPSearch hosts an AXIS service for remote deployment of scripts
HPSearch (Danube)
PI Code Runner (Danube)
Accumulate Data
Run PI Code
Create Graph
Convert RAW -> GML
GML (Danube)
Actual Data flow
HPSearch controls the Web services
Final Output pulled by the WMS
HPSearch Engines communicate using NB Messaging infrastructure


Select Layers for World_Seismic
World:Base
California:States
World:Seismic
Update Layer List
Select Area of Interest
Zoom to ...
Resize Map :
X
400 x 300
Time Interval for Seismic Data
(Month / Day / Year)
From : 01 / 01 / 1992
To : 12 / 31 / 1992
Min Magnitude : 4
RUN PI CODE
PLOT PI OUTPUT
Display the PI Output
World_Seismic Data
126.21
132.15
138.09
144.04
149.98
49.42
43.14
36.87
30.59
24.31
0-km
738.36-km
1,476.72-km
2,215.09
COORDINATES (according to SRS) LON : 137.68 LAT : 41.22
0 m
pi - Microsoft Internet Explorer

Some Challenges

- **Performance:** Are GIS services suitable for non-trivial data transfers?
  - Entire California seismic record since 1932 is 12 MB.
  - Global records obviously larger
  - This is not really suitable for HTTP transport.
  - We more recently implemented streaming data transfers for higher performance.
- **Adoption:** We must get the tools and services to the point where science application developers want to use them *early* in the development process rather than *later*.
  - Web Service client libraries to remote GIS data
  - Develop codes to work with data streams rather than files.
- **Security:** A global version of this has interesting security requirements
  - Authentication, authorization, federation for different countries
  - Time/event dependent security for crisis response

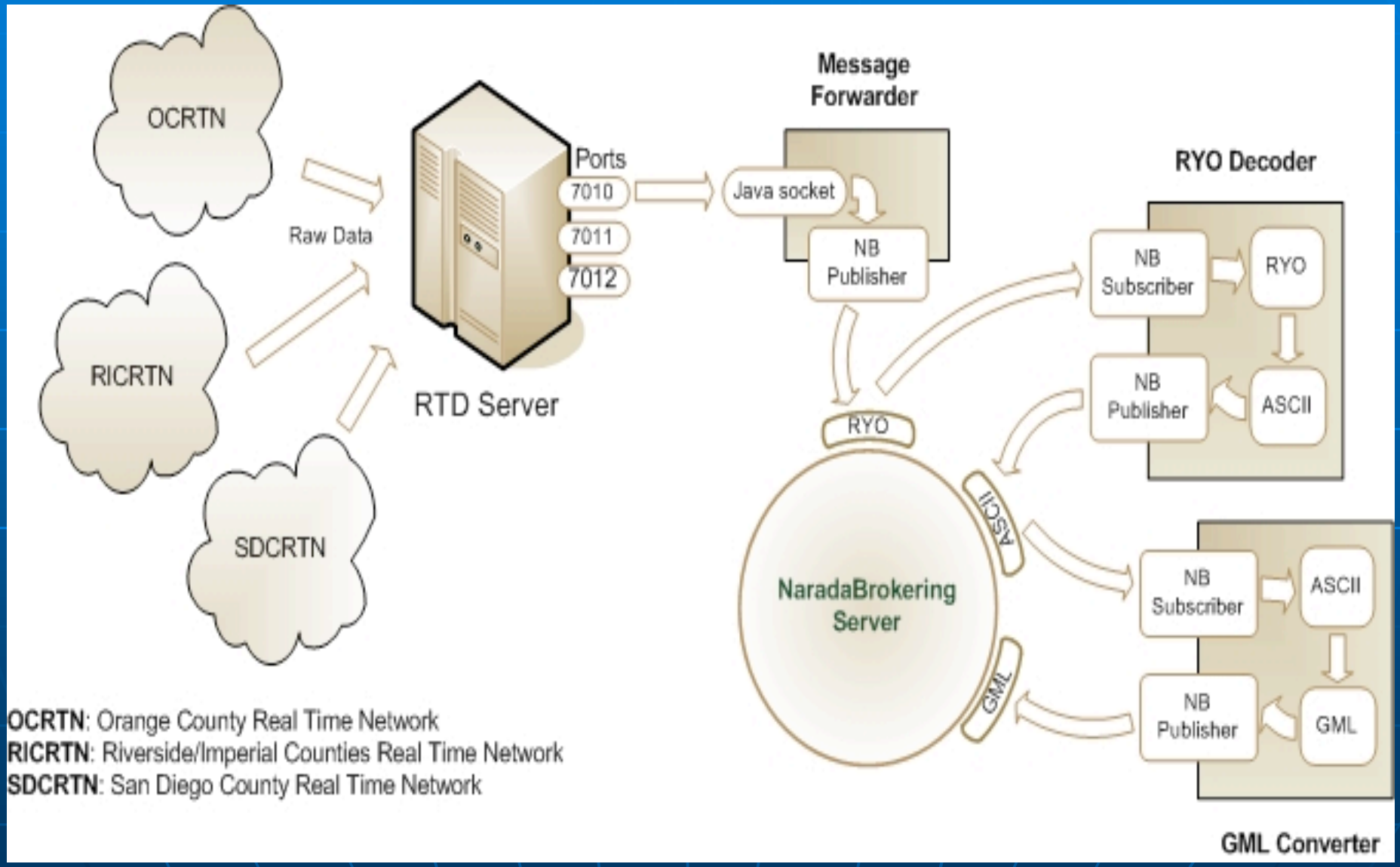
Sensor Grid

- A flexible computing environment for coupling real-time data sources to High Performance Geographic Information Systems (GIS) applications.
- Basing this on Open Geospatial Consortium's SensorML suite
  - SensorML provides metadata about sensors
    - In development
  - Observations and measurements extensions to GML.
    - Currently implemented
- Codes such as RDAHMM can analyze real-time data for state change detection in GPS and other time series data.
  - Individual GPS state changes can be monitored and aggregated to detect changes in GPS networks.
- We are implementing this in conjunction with Scripps and JPL

Support for Streaming Data

- We use NaradaBrokering messaging software to manage data streams and filters.
  - Open source, Java-based software from the Community Grids Lab
  - Based on topic-based publication/subscription for delivery of messages from/to multiple endpoints.
  - "Message" can be anything, including SOAP and binary data streams.
  - We use this for audio/video collaboration.
  - More recently using it to build Web Service messaging substrates
    - SOAP 1.2 routing model, WS-Reliability, WS-Eventing
- NB ensures reliable delivery of events in the case of broker or client failures and prolonged entity disconnects.
  - Also supports replay.
- Implements high-performance protocols (message transit time of 1 to 2 ms per hop)

SOPAC GPS Services



SOPAC GPS Services

- As a case study we implemented services to provide real-time access to GPS position messages collected from several SOPAC networks.
- Next step is to couple data assimilation tools (such as RDAHMM) to real-time streaming GPS data.
- Next steps
  - Programming APIs: currently we assume the subscriber speaks NaradaBrokering Java APIs (either NB's native API or Java Messaging Service).
    - Need to investigate appropriate Web Service standards and C/C++ bindings.
  - SOAP enveloping of the GML message stream.
  - A Sensor Collection Service will be implemented to provide metadata about GPS sensors in SensorML.

Position Messages

- SOPAC provides 1-2Hz real-time position messages from various GPS networks in a binary format called RYO.
- Position messages are broadcasted through RTD server ports.
- We have implemented tools to convert RYO messages into ASCII text and another that converts ASCII messages into GML.

Real-Time Access to Position Messages

- We have a Forwarder tool that connects to RTD server port to forward RYO messages to a NB topic.
- RYO to ASCII converter tool subscribes this topic to collect binary messages and converts them to ASCII. Then it publishes ASCII messages to another NB topic.
- ASCII to GML converter subscribes this topic and publishes GML messages to another topic.

GPS Stations

- Current implementation provides real-time access to GP messages to following stations in RYO, ASCII and GML formats:

RTD Port No	7010	7011	7012
GPS Network	Orange County	Riverside/Imperial Counties	San Diego County
	AZRY	BLSA	DSME
	COTD	CAT2	DVLW
	CRRS	FVPK	OGHS
	DHLG	MJPK	PMOB
	DVLE	OEOC	RAAP
	GLRS	SACY	SIO5
	KYVW	SBCC	
	PIN1	SCMS	
	PIN2	TRAK	
	PSAP	WHYT	
	SLMS		
	WIDC		

NaradaBrokering topics

NaradaBrokering Server: xsopac.ucsd.edu:3045

Network	Format	NB Topic
OCRTN	RYO	SOPAC/GPS/Positions/OCRTN/RYO
	ASCII	SOPAC/GPS/Positions/OCRTN/ASCII
	GML	SOPAC/GPS/Positions/OCRTN/GML
RICRTN	RYO	SOPAC/GPS/Positions/RICRTN/RYO
	ASCII	SOPAC/GPS/Positions/RICRTN/ASCII
	GML	SOPAC/GPS/Positions/RICRTN/GML
SDCRTN	RYO	SOPAC/GPS/Positions/SDCRTN/RYO
	ASCII	SOPAC/GPS/Positions/SDCRTN/ASCII
	GML	SOPAC/GPS/Positions/SDCRTN/GML

More Information

- Contact: mpierce@cs.indiana.edu
- GIS Work at CGL: www.crisisgrid.org
  - Software, demos, publications
  - Several recent manuscript submissions are/will be posted soon.
- HPSearch at CGL: www.hpsearch.org
- SERVOGrid Web Sites
  - Our fine parent project
  - http://servo.jpl.nasa.gov/
  - http://quakesim.jpl.nasa.gov/

Status and Software

- Web Feature Service 1.x software available now
  - www.crisisgrid.org
- Our SERVO WFS includes
  - Fault data
  - GPS records
  - Seismic records now for most areas of the globe
  - Note these are Web Services, so you can build your own clients to connect to our running services.
- Web Map Service
  - Client portlets (shown) available from www.collab-ogce.org.
  - Server software downloads available soon.
- HPSearch
  - Currently available, www.hpsearch.org
- WS-Context and Information Services Work
  - http://grids.ucs.indiana.edu/~maktas/fthpis/

Acknowledgements

- Prof. John Rundle and his group at UC-Davis, particularly James Holliday.
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  - Mehmet Aktas: Information and Context Services
  - Harshawardhan Gadgil: HPSearch Workflow development
- Satellite images from NASA OnEarth WMS
- This work is supported by the NASA Advanced Information Systems Technology Program.

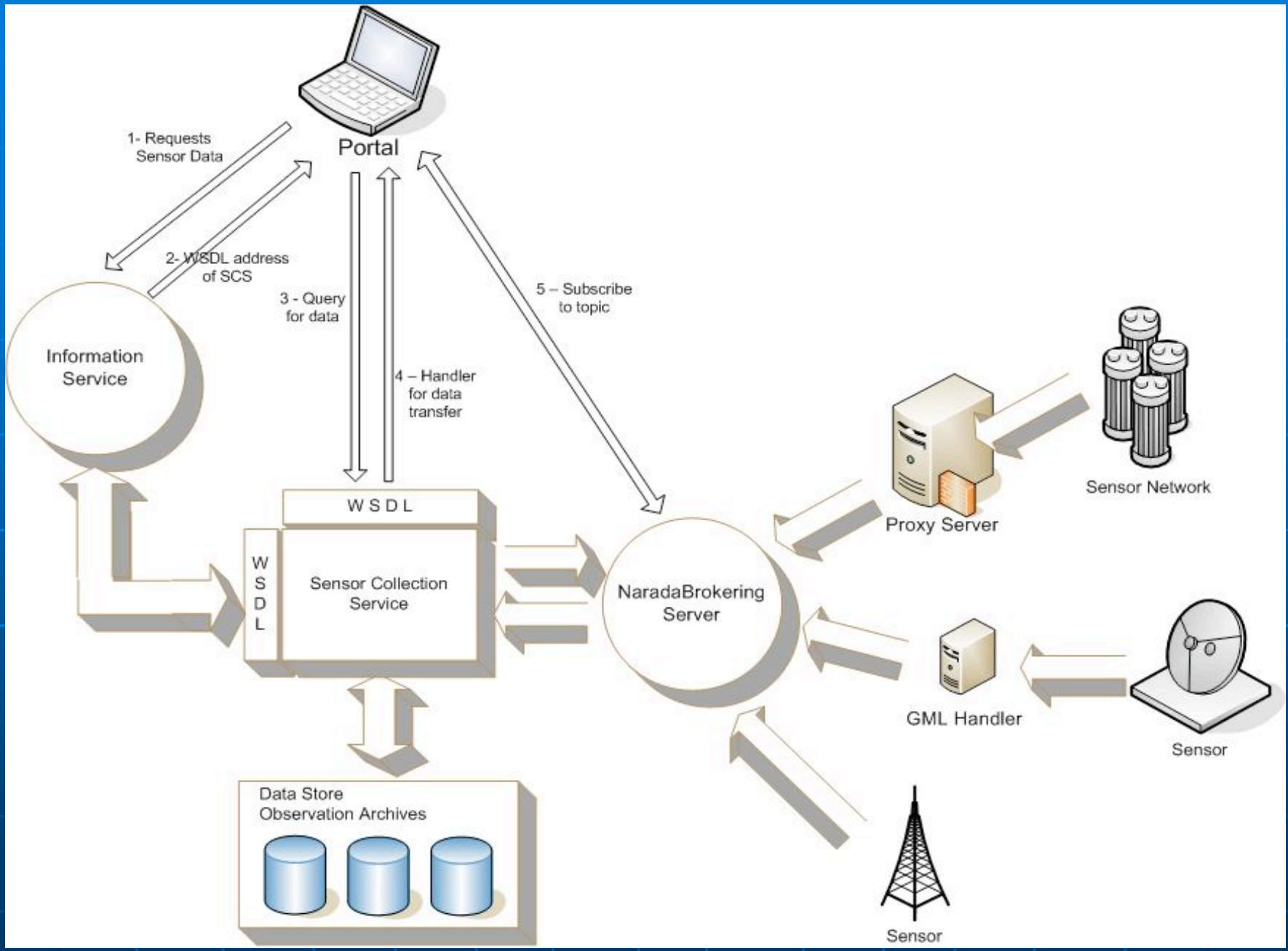
Backup Slides

Open Standards

- SensorGrid will combine Open GIS standards for data and services with Web Services specifications.
- GML and SensorML, OGC (Open Geospatial Consortium Inc.) specifications for encoding geospatial data and sensor metadata in XML will be adopted for universal compatibility with larger GIS community.
- WS-* specifications will be utilized to ensure access to these data via standard interfaces.

CGL Work on GIS Services

- Some example OGC services include
  - Web Feature Service (WFS): for retrieving GML encode features, like faults, roads, county boundaries, GPS station locations,….
  - Web Map Service (WMS): for creating maps out of Web Features
- Problems with current GIS services
  - Not (yet) Web Service compliant
    - Efforts underway to provide this within OGC.
    - But current specs are “pre” web service, no SOAP or WSDL
    - Use instead HTTP GET/POST conventions.
  - Often define general Web Service services as specialized standards
    - Information services
    - Notification services in sensor grids
  - Can’t use other Web Service standards for reliability, security, etc.
- CGL is developing Web Service versions of OGC standard services


Portal
1- Requests Sensor Data
2- WSDL address of SCS
3 - Query for data
4 – Handler for data transfer
5 – Subscribe to topic
Information Service
W S D L
W S D L
Sensor Collection Service
NaradaBrokering Server
Proxy Server
Sensor Network
GML Handler
Sensor
Data Store
Observation Archives
Sensor

Select Layers for World_Seismic

- [x] World:Base
- [ ] California:States
- [x] World:Seismic

Update Layer List

Select Area of Interest

Zoom to ...

Resize Map : X

400 x 300

Time Interval for Seismic Data
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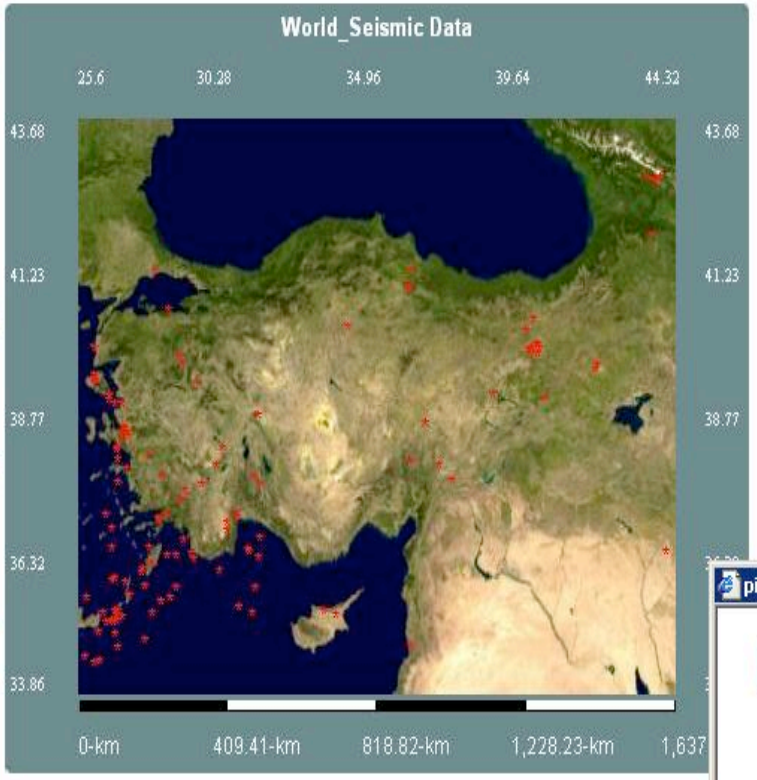

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0 m