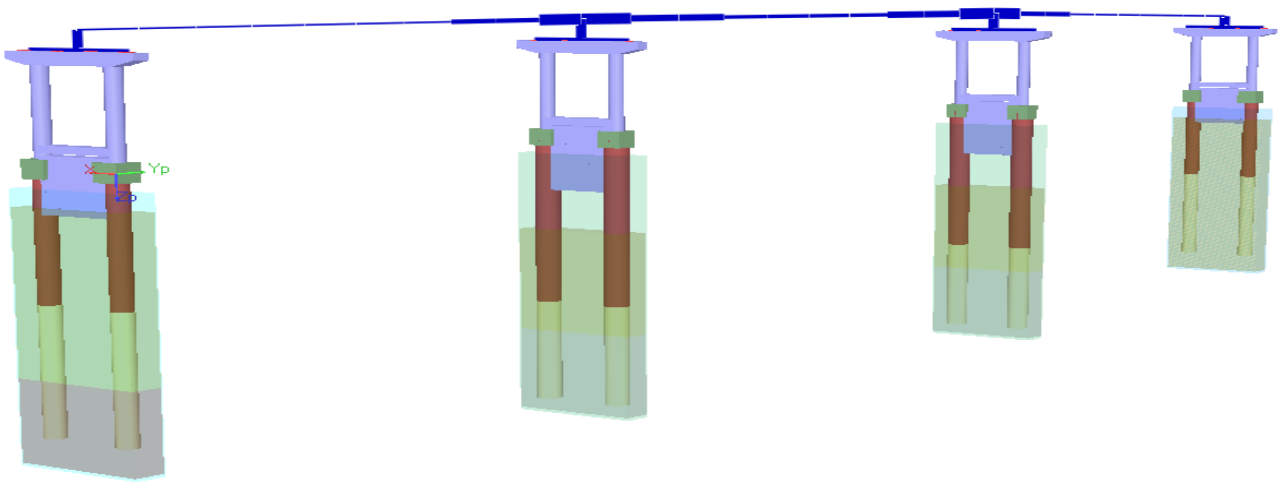
Structural Engineering: An Overview of Global Directions



Marc Hoit, Ph.D.

Vice Chancellor for IT

Professor of Civil Engineering

Overview

- Global trends affecting education
- Technology impact on learning and behavior
- Considerations for structural education & practice
- Two examples of technology enhancements
  - FB-MultiPier
  - DIGGS

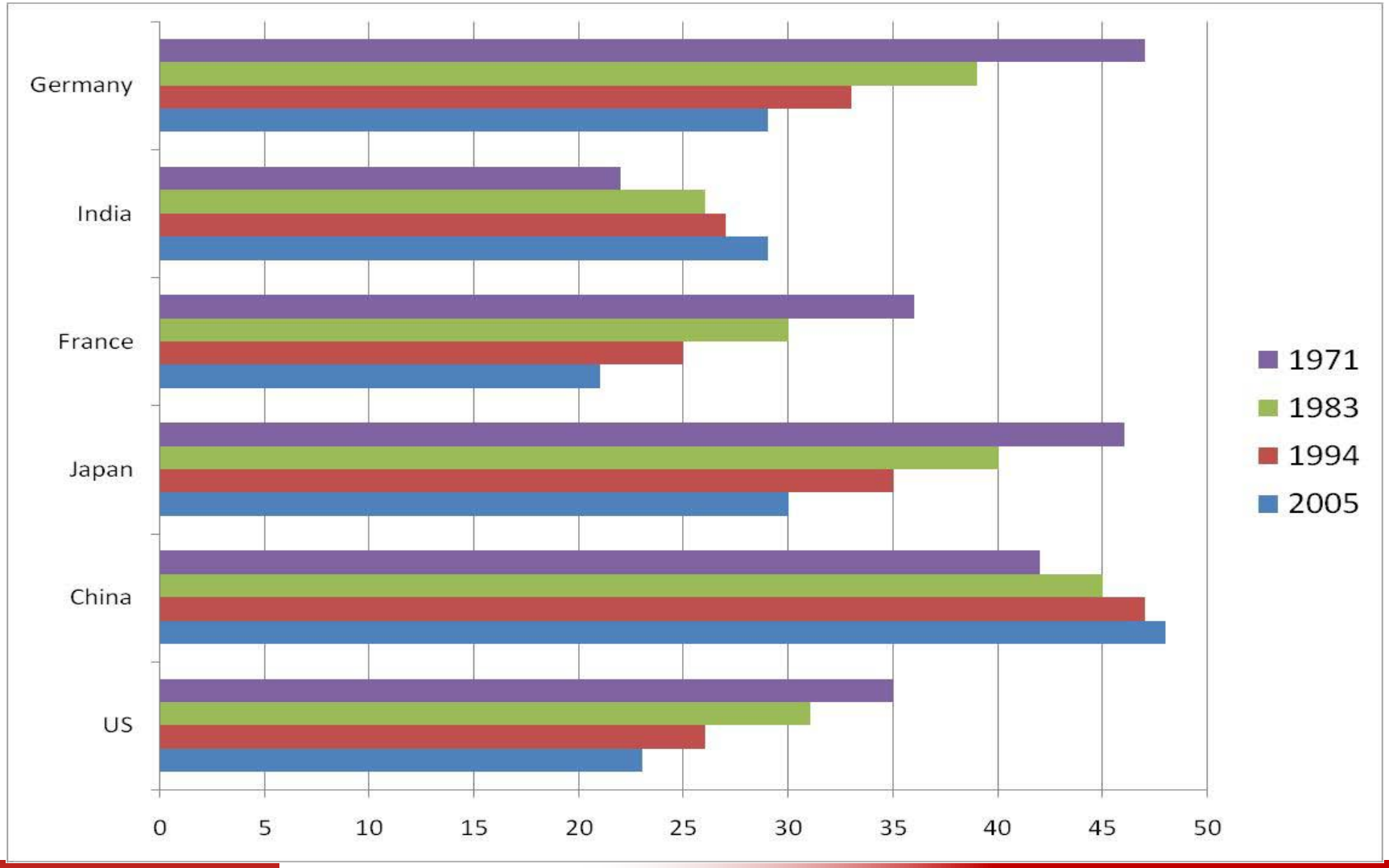
"In God we trust," she said. "All others, bring data."

~Margaret Spellings~

Secretary of Education

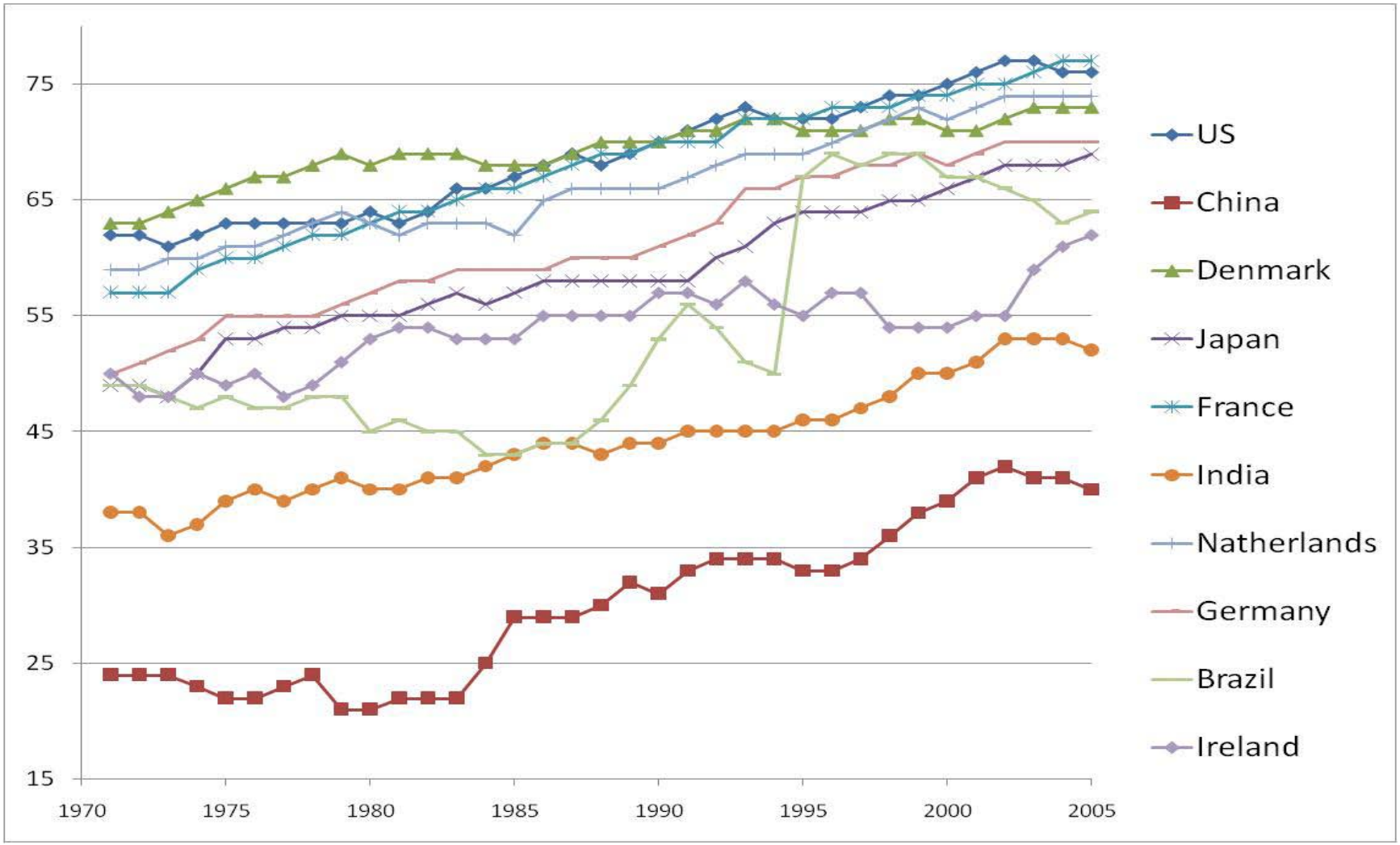
Industrial Value Added (% GDP)

From World Bank Data



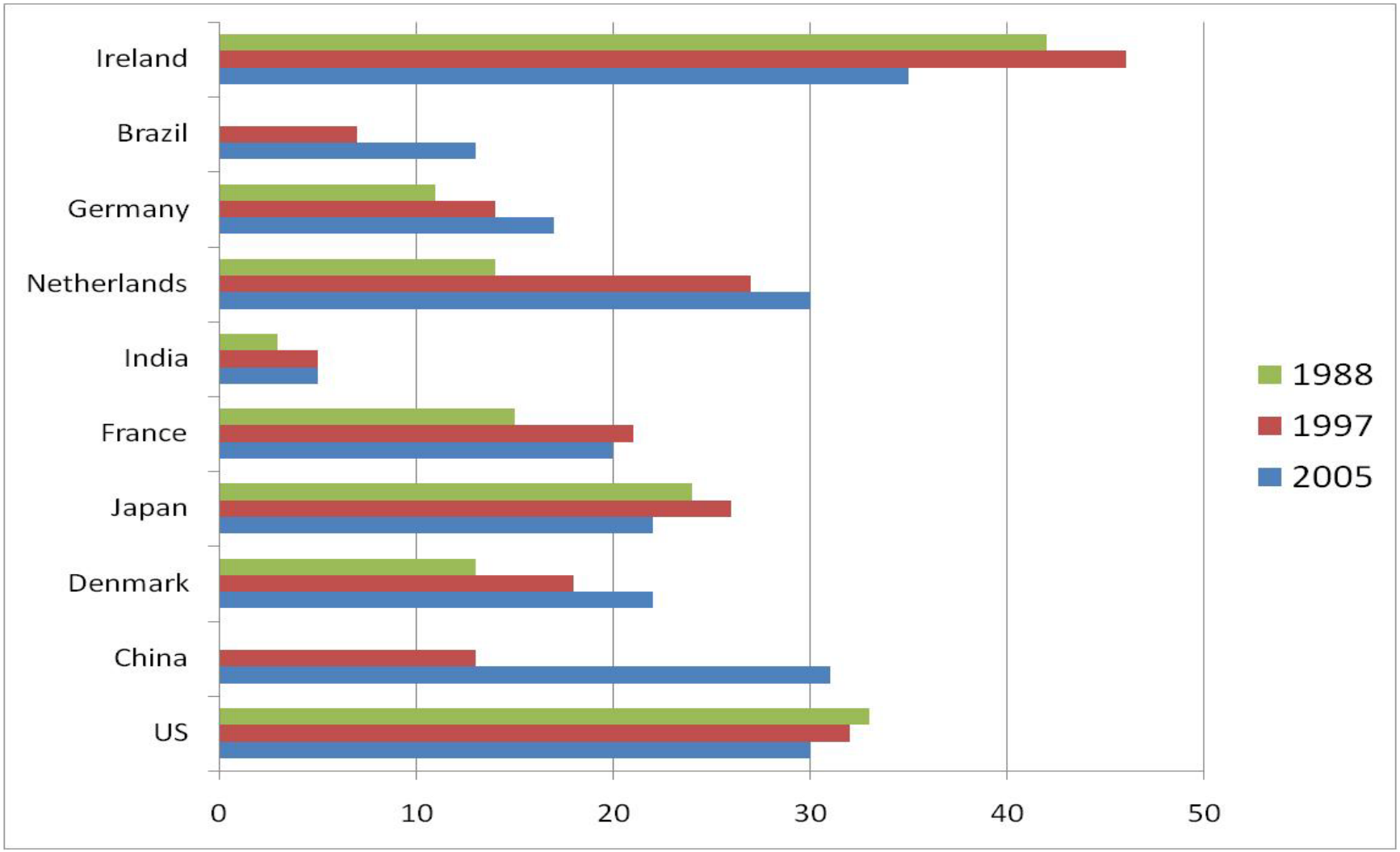
Service Value Added (% GDP)

From World Bank Data



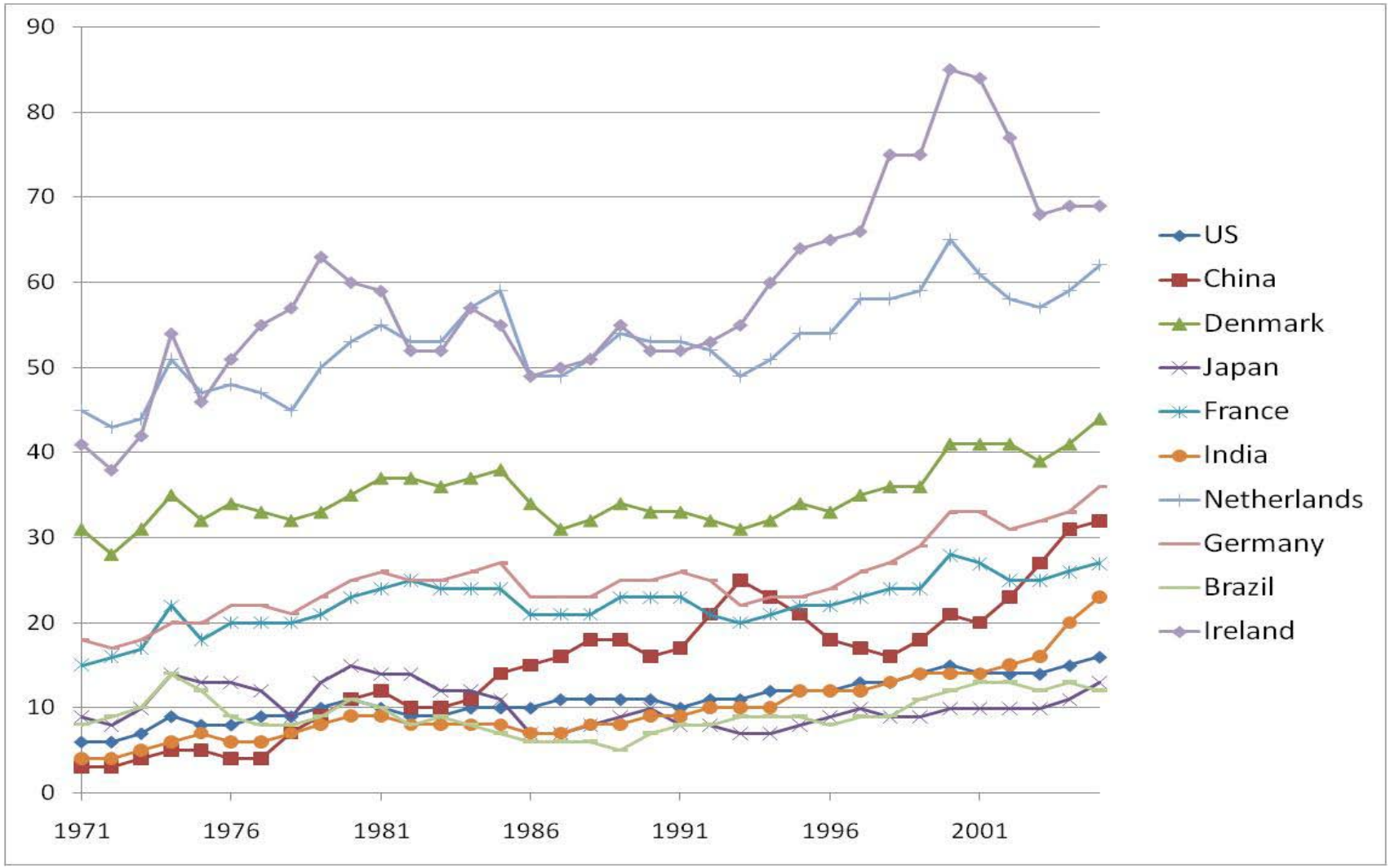
High Tech Exports (% Manufactured Exports)

From World Bank Data



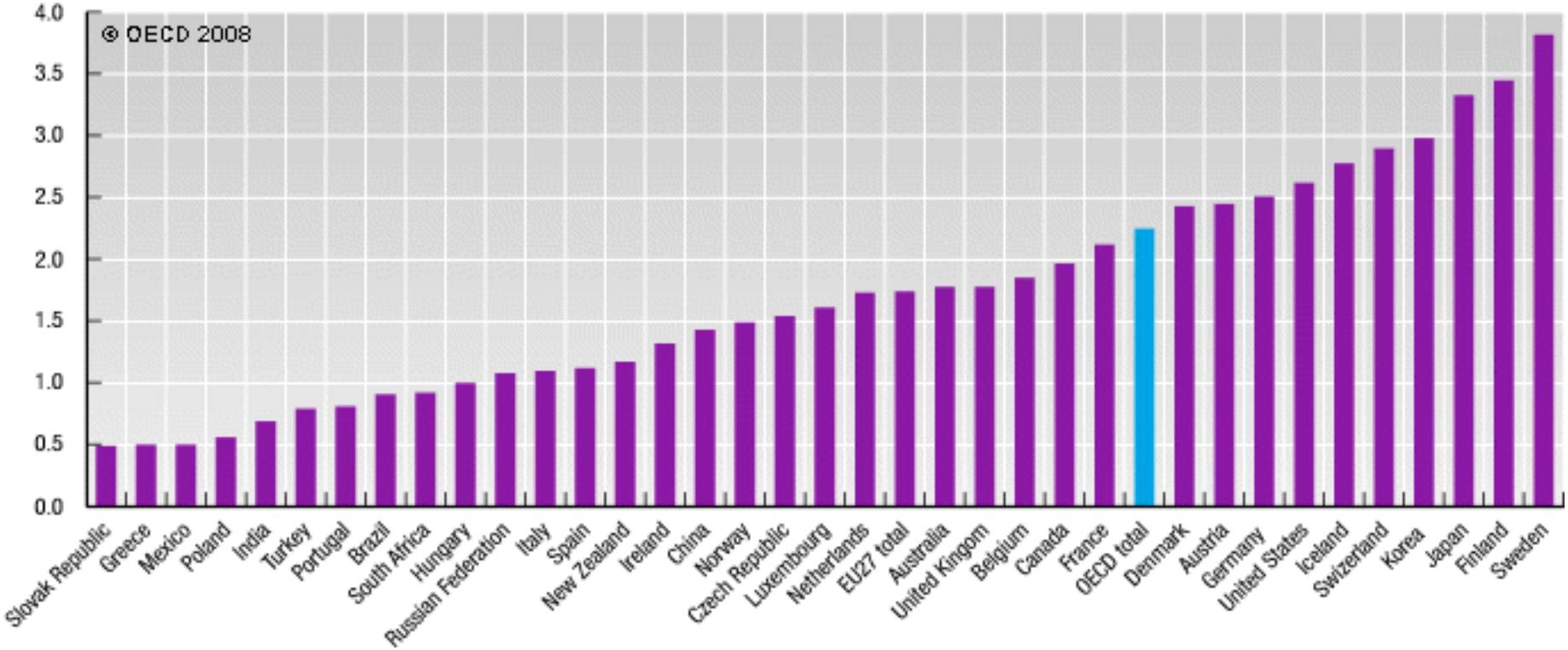
Import of Goods and Services (% GDP)

From World Bank Data



Gross domestic expenditure on R&D

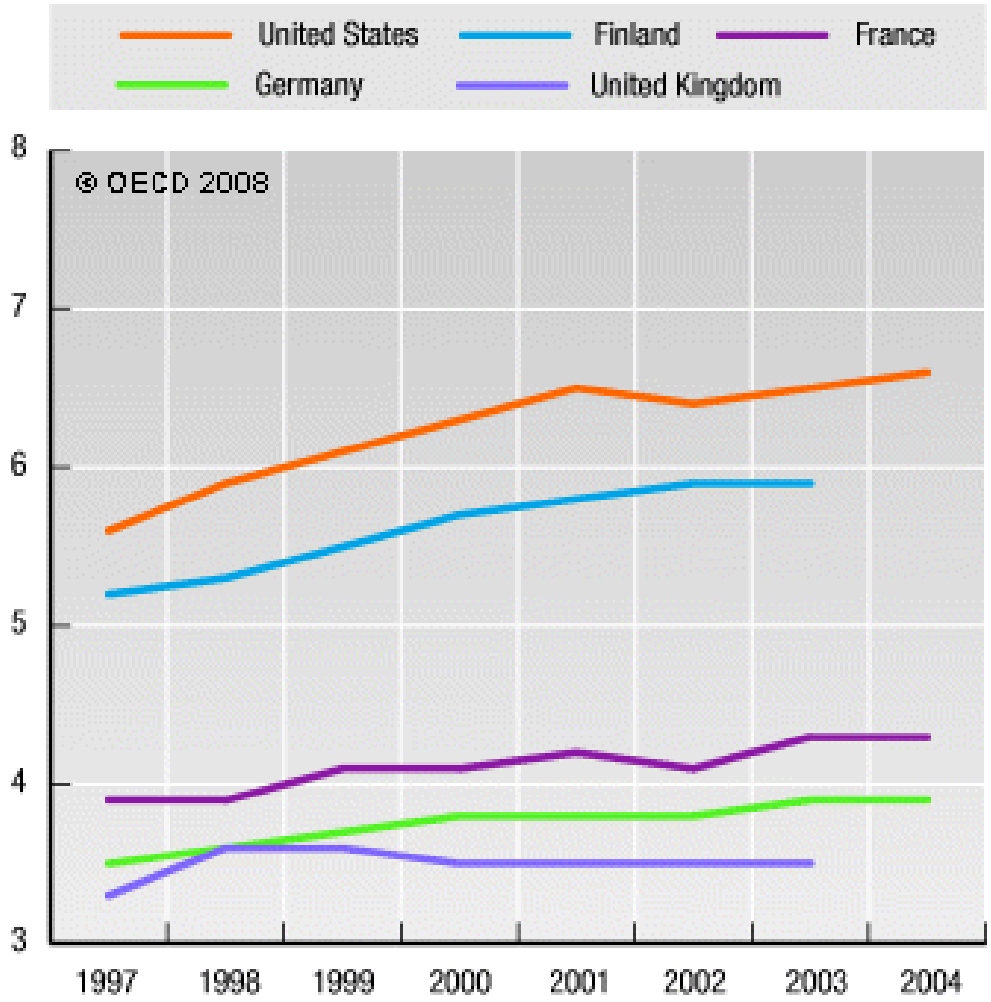
As a percentage of GDP, 2006 or latest available year



From Organization for Economic Co-Operation and Development (OECD)

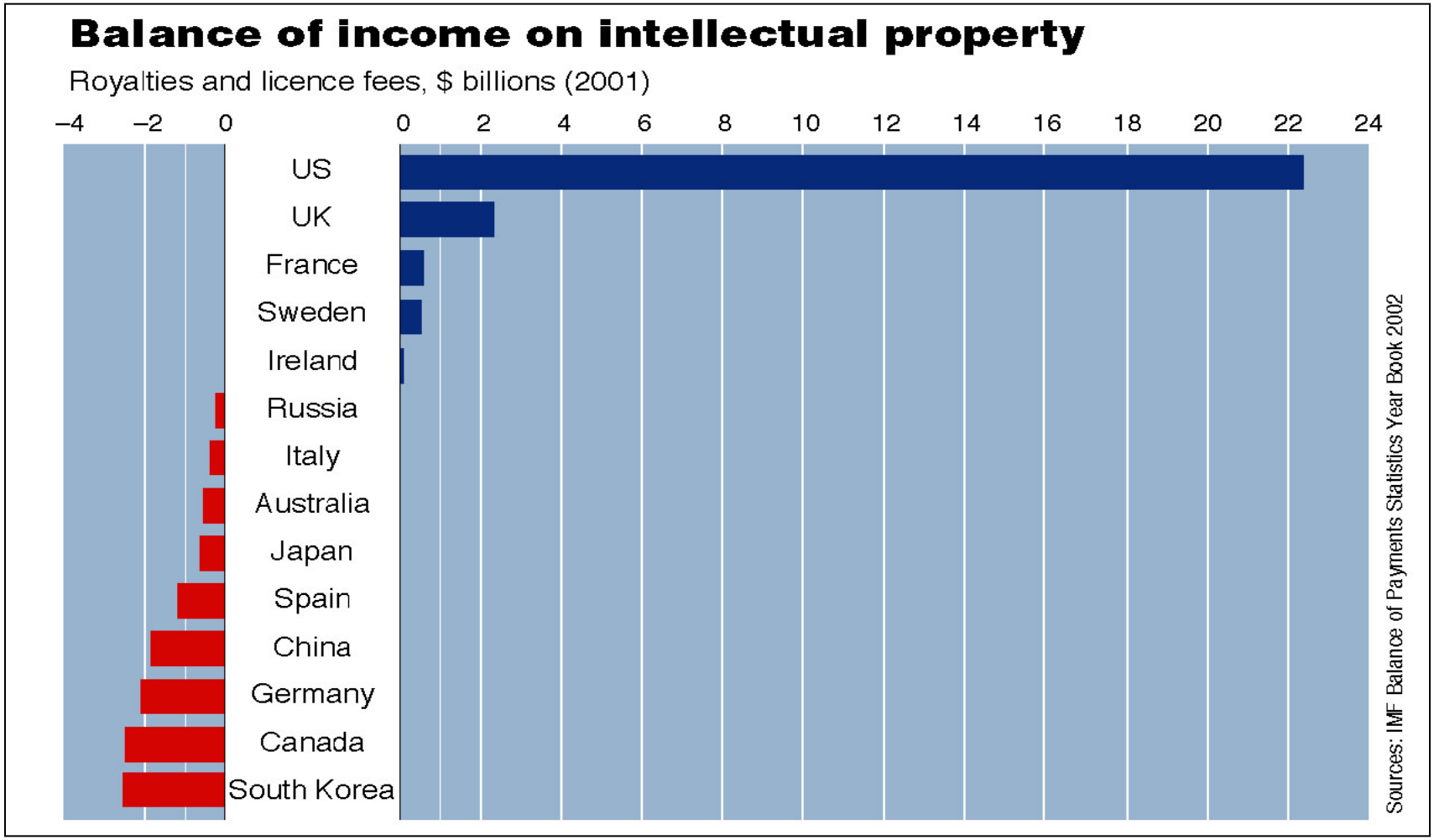
Investment in knowledge (% GDP)

(Expenditure on R&D, Higher Ed, Software)



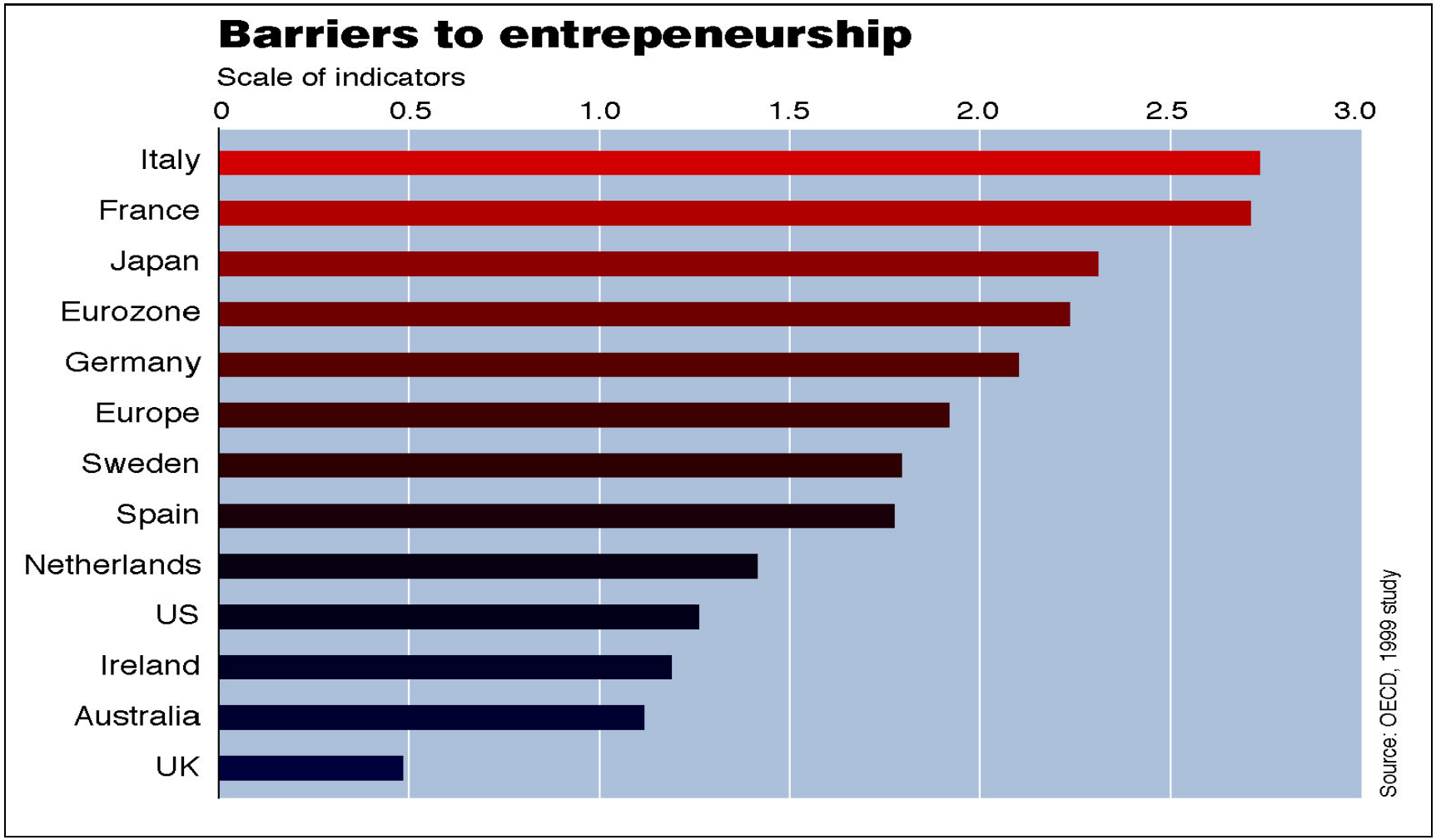
From Organization for Economic Co-Operation and Development (OECD)

IP Generation by Country



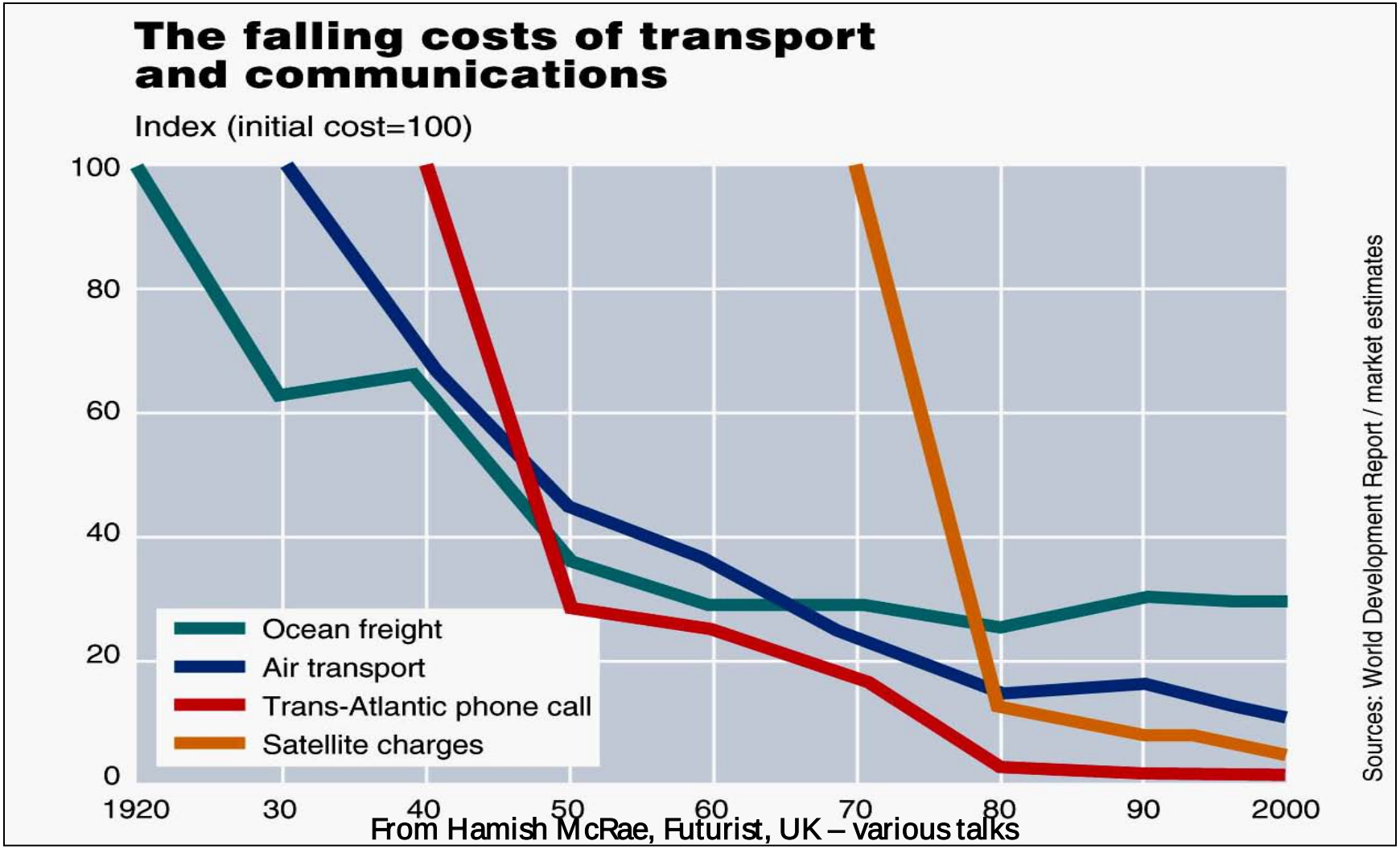
From Hamish McRae, Futurist, UK – various talks

Ease of Starting New Businesses



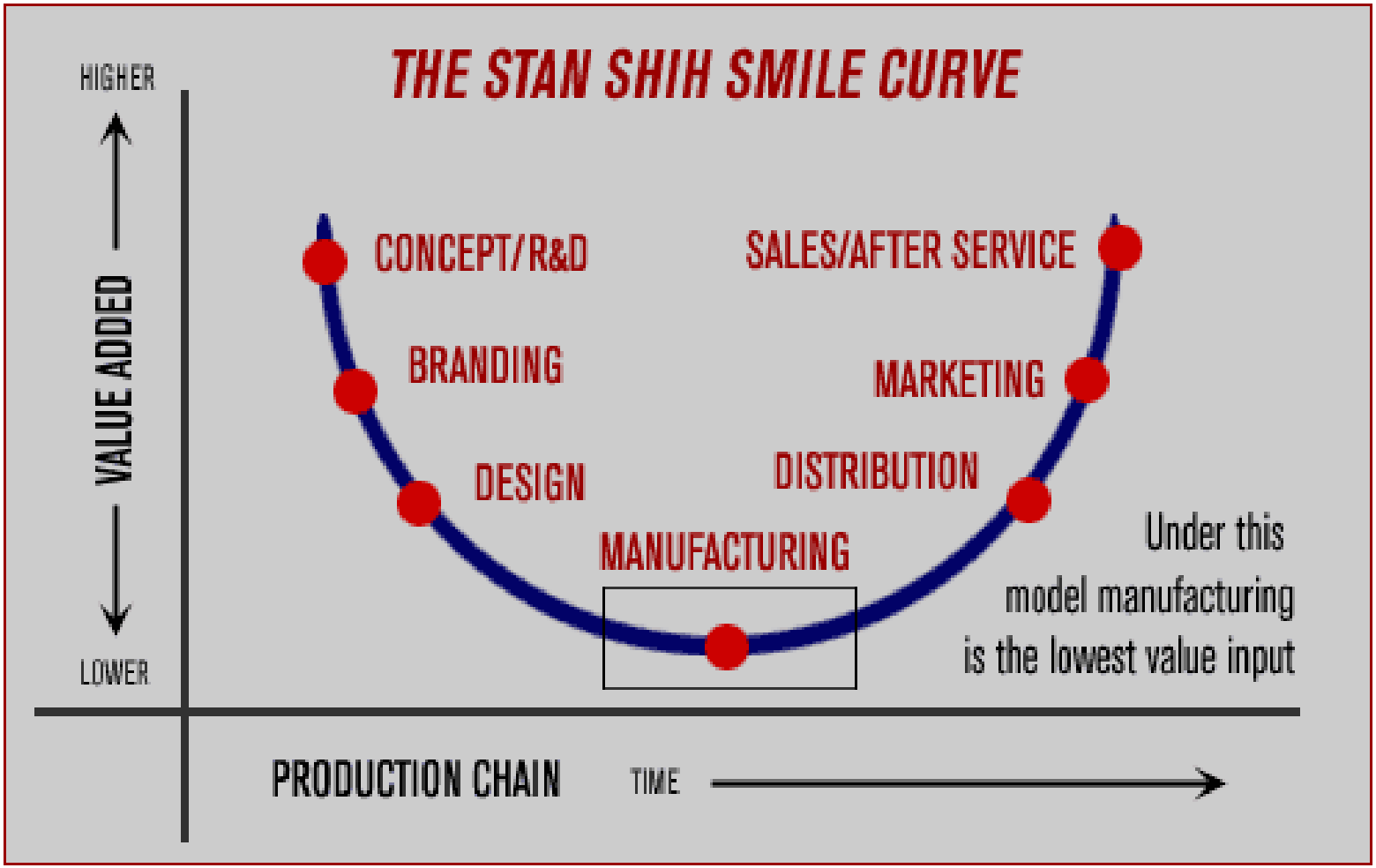
From Hamish McRae, Futurist, UK – various talks

Communication Costs Essentially Zero



From Hamish McRae, Futurist, UK – various talks

Work Where the Value Is



Stan Shih, Founder of Acer, Taiwan, 1992

The Horizon Report 2008

The New Media Consortium and the EDUCAUSE Learning Initiative

- Grassroots Video
  - Virtually anyone can capture, edit, and share video clips.
- Collaboration Webs
  - Collaboration no longer calls for expensive equipment
- Mobile Broadband
  - Each year more than a billion new mobile devices are manufactured[1]
- Data Mashups
  - Multiple sources of data merged together provide new insight
- Collective Intelligence
  - Hive, crowd sourcing, open source,…
- Social Operating Systems
  - Organize around people not content

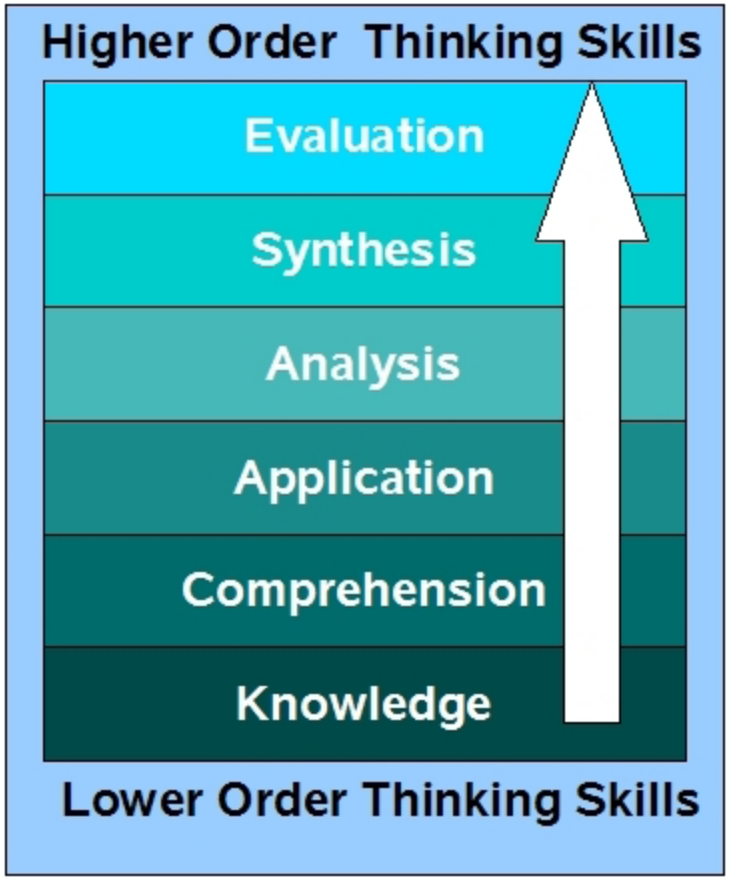
Expect Increased Demands for Information Access and Malleability

- All time access to all your services
  - Phone browsing is just the beginning
- Easy to use technology (no users manual)
- Analytics rule – predictive modeling
  - Amazon "people who have … also considered…"
- Shared Data
  - Interlinked/connected – Web services, Mash-ups, cloud
- Identity Management
  - Know who you are and trust it is you
    - Security & Compliance, Shibboleth, grid computing, true "cloud computing"
- Outsourced components as appropriate
  - Industry leads, Higher Ed embracing now – (SaaS, Google apps, MS Live, Facebook for collaboration,)

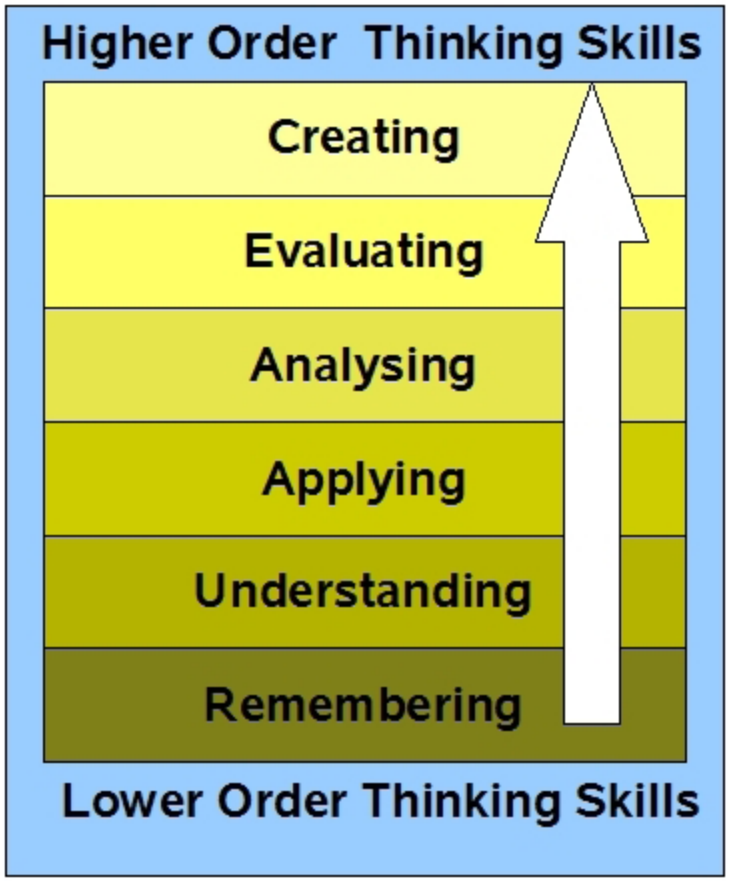
Higher Ed: What does it mean for us?

- Electronic platform delivery (growth, on-campus, flexibility)
- Focus on advanced degrees
- Educate for the “Smile”
  - Creativity as fundamental education
  - Entrepreneurs – Need to foster cognitive diversity
  - Develop champions in science (biology, nano, physics)
  - Creation of new intellectual property (innovation)
- IT as an accelerator for research
  - Collaboration
  - High performance computing in all fields
- Increased expectations for service delivery

Bloom's Digital Taxonomy – Premium on Higher Order Skills



Bloom's Taxonomy



Bloom's Digital Taxonomy

From: Andrew Churches (http://edorigami.wikispaces.com/file/view/bloom%27s+Digital+taxonomy+v2.12.pdf)

Work Style of “Digital Natives”

work from Prensky, 2001

Create	Find	Organize	Interact
Creating	Searching	Analyzing	Meeting
Learning	Collecting	Evaluating	Gaming
Evolving	Exchanging	Reporting	Socializing
Growing Up	Buying	Selling	
Programming			
Sharing			
Communicating			
Coordinating			

Gartner, Inc.., “IT-Based Collaboration and Social Networks Accelerate R&D” by Carol Rozwell, January 2008

Culture Change: Digital Natives

- Millennial Generation has grown up with technology, it's use and on-demand access to information.
  - There is evidence that neurological changes are occurring
  - Gaming has shown improved creative thinking
- Newer generations have always adapted, taken it for granted and innovated new technologies
  - Telegraph, Dial a phone, wireless, typewriter
- Understanding of the underlying concepts of the technology and it's adaptation and applications has (and will always) be the generator of change
  - As these ideas are automated and simplified, they become usable by all under the rules from which they have been developed

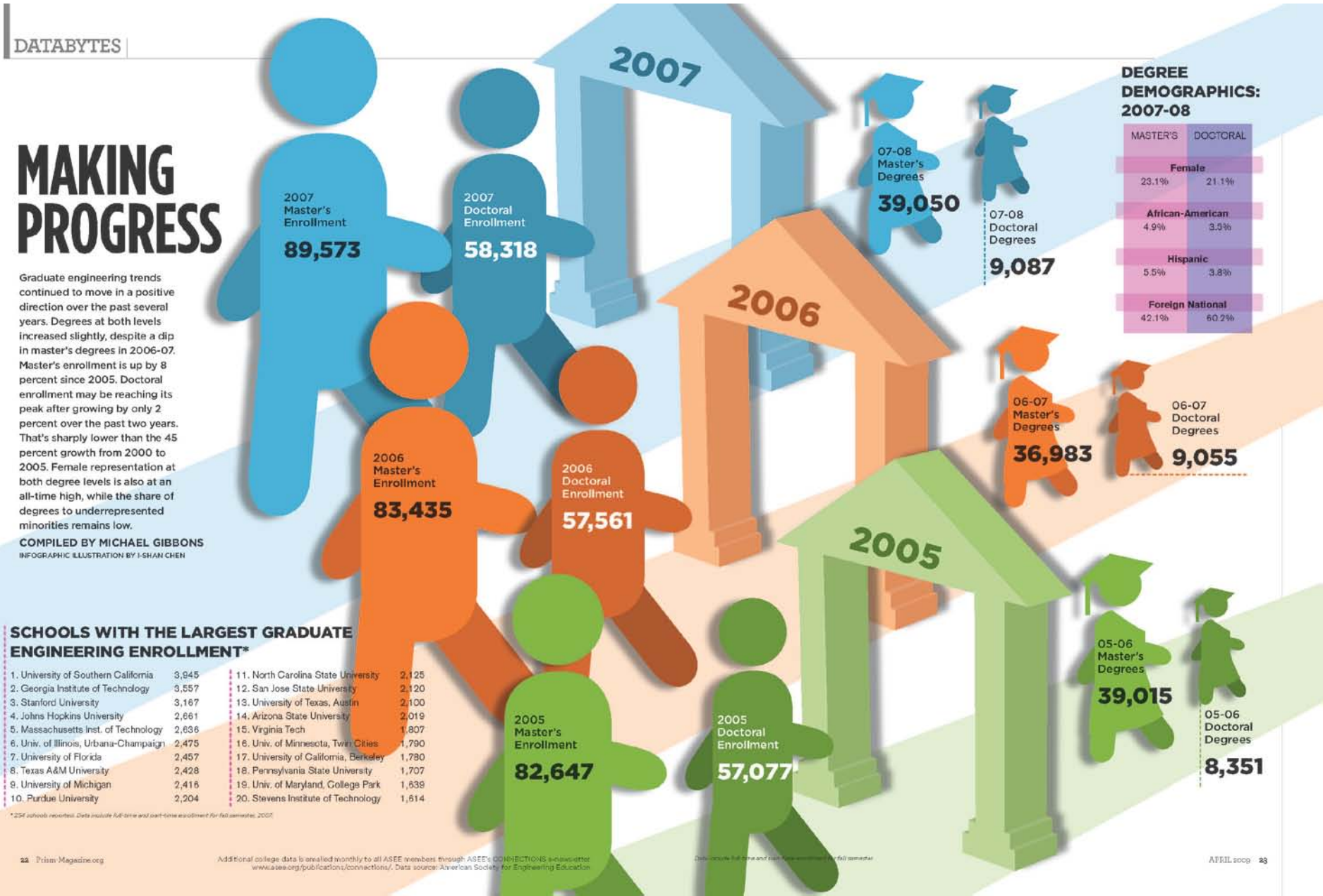
“Imagination is more important than knowledge.”

~Albert Einstein~

NC State University: Delivering Innovation & Positioned to Lead

- Innovative campus programs
  - Centennial Campus – A model for University/Industry partnership
  - FREEDOM Center, Digital Games Research Center, Entrepreneurs Program, Friday Institute, Institute for Advanced Analytics, Undergraduate Research
  - Technology transfer success
    - 623 Patents, 72 Start-up companies (Company Spin offs: Red Hat, Cree, VCL (Apache.org), …
- State and Region leader in Innovation
  - Research Triangle Park (Model for countries to build capacity)
  - NC Government – understands and fosters Economic Development and Higher Ed linkage

NC State #11 in Grad Enrollment (2,125)



Ideas for Structural Engineering

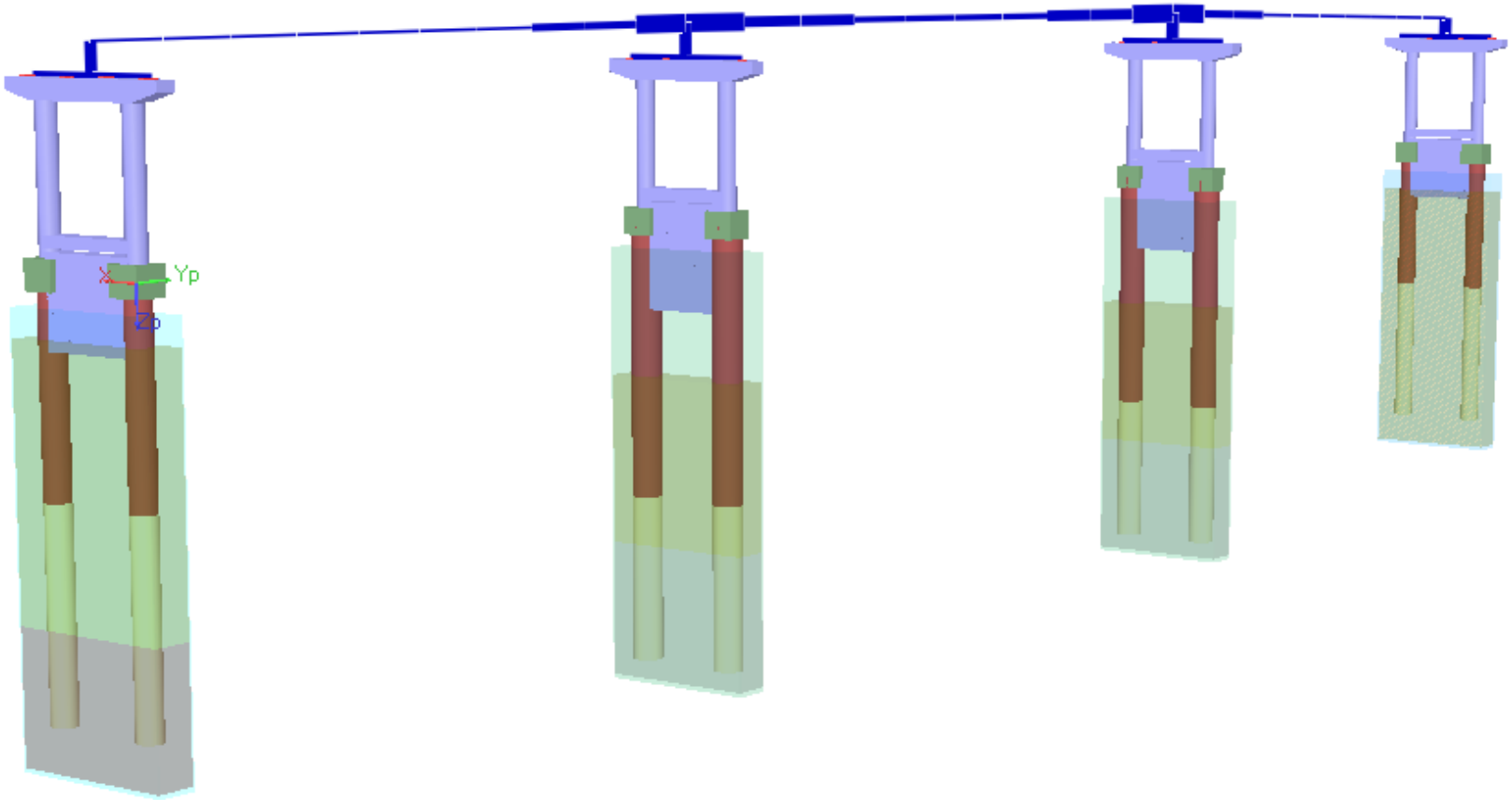
- Engineering needs to be part of the leading trends
  - Improve teaching (relevance of place)
    - Recent articles in Structure Magazine
      - Are We Relying Too Much On Computers? (Powell)
        - *Phases: Modeling, Number Crunching and Interpretation*
        - ***Too much time number crunching!***
      - Alternatives to Matrix Methods (Hoit)
  - Innovate in research
  - Partner and collaborate
  - Incorporate right brain thinking

Two examples:

Example 1:
SR 20 / Apalachicola River Bridge Construction

SR 20 / Apalachicola River Construction Site
(viewed from the East, 1997)

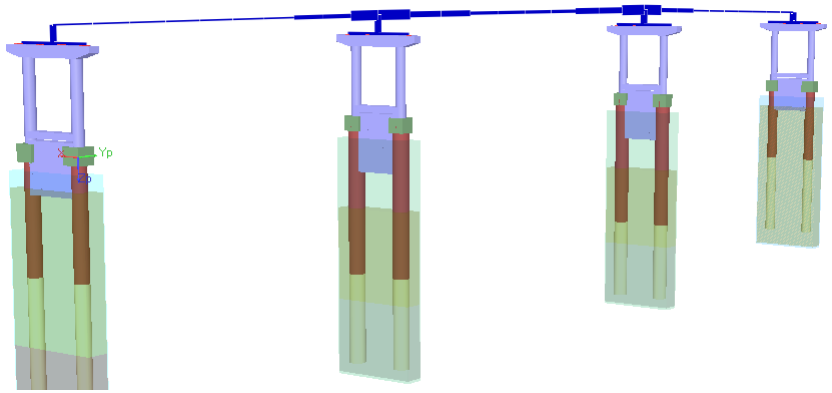
FB-Multipier model of SR 20 / Apalachicola River Bridge



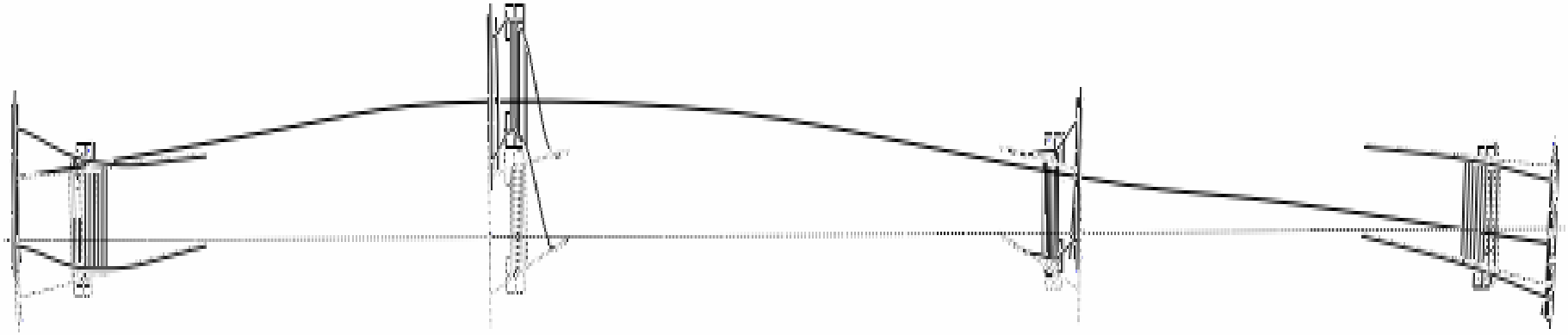
224/280/224 ft steel spans across the river

Case Study - 2550 kips at Pier 2

- Case I : Guided Bearings



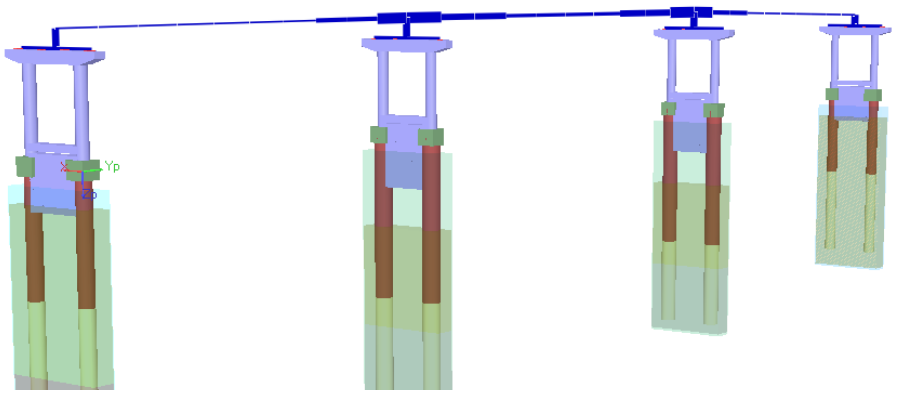
Plan view shows relation of deck to substructure when bearings ARE guided. (400 kips are transferred



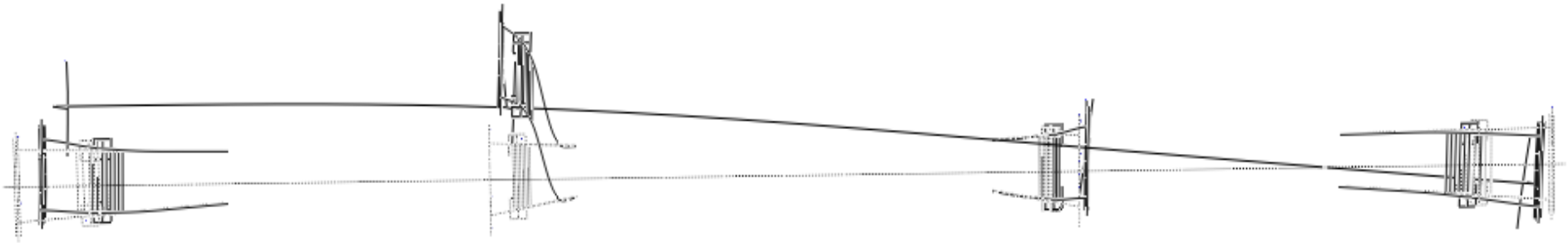
Plan view of deformed bridge (scaled up 200 x)

Case Study - 2550 kips at Pier 2

- Case II : Un-Guided Bearings



Relation of deck to substructure:
130 kips are transferred to deck when bearings are NOT guided.



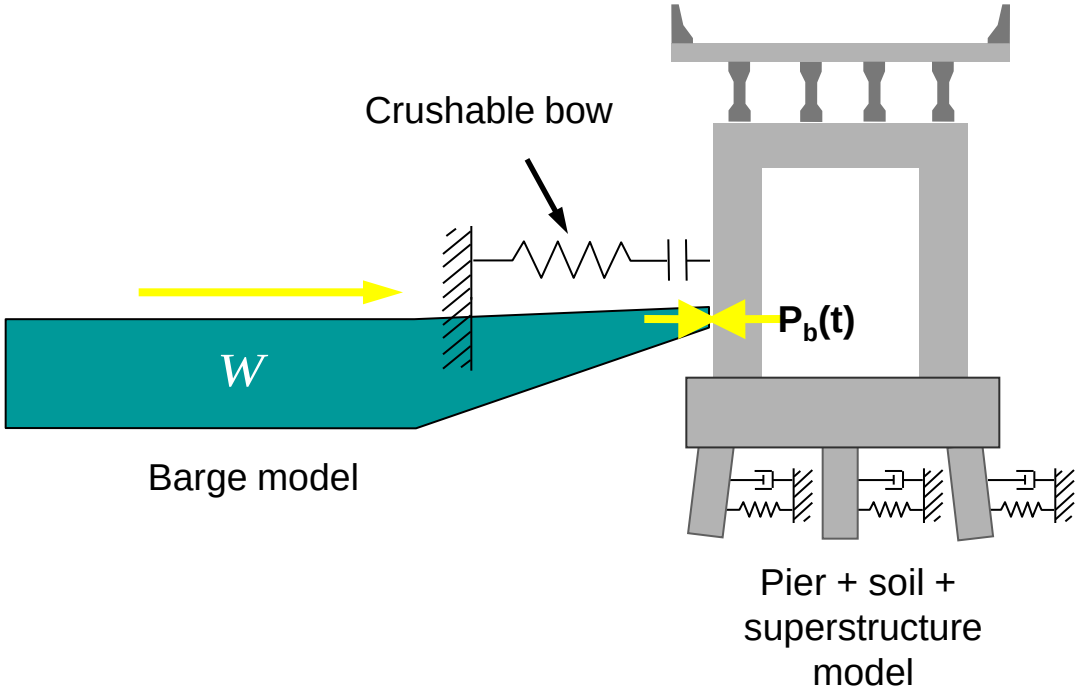
Barge Impact Tests at St George Island Bridge

Barge Impact Tests were conducted at St. George Island Bridge during March / April 2004. A total of 15 impact tests were conducted

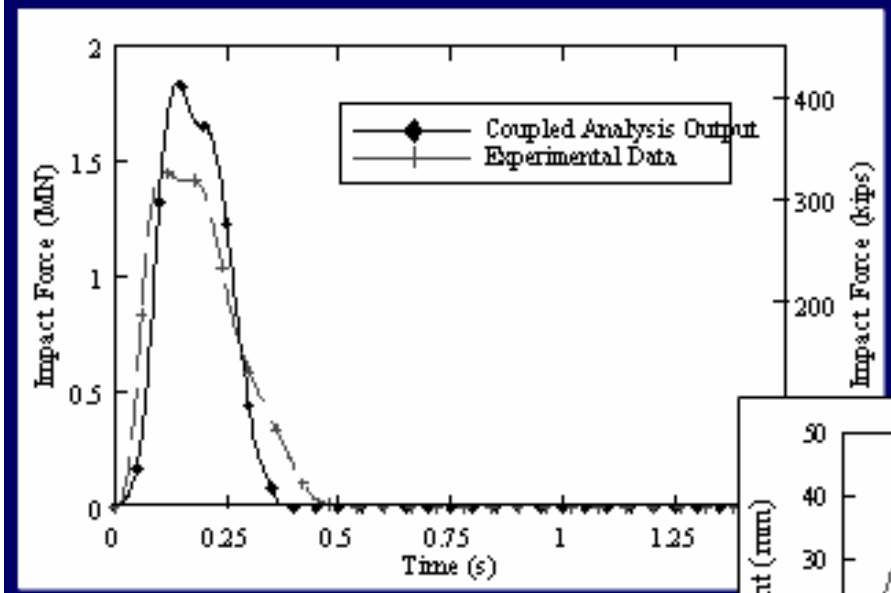
Courtesy of UF Structure Research Group, Gary Consolazio et al.

Coupled Vessel Impact Analysis of FB-Multipier

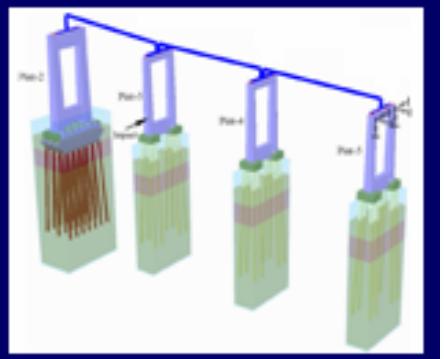
- Dynamic bridge model (FB-MultiPier)
- Simplified dynamic barge model
- Crushable barge bow section

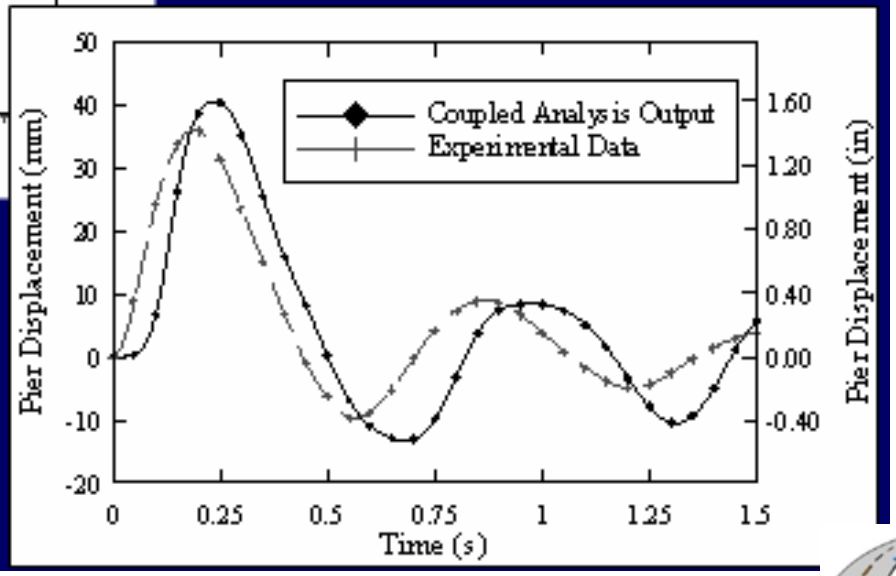


Validation of Coupled Vessel Impact Analysis (CVIA) Models of FB-Multipier



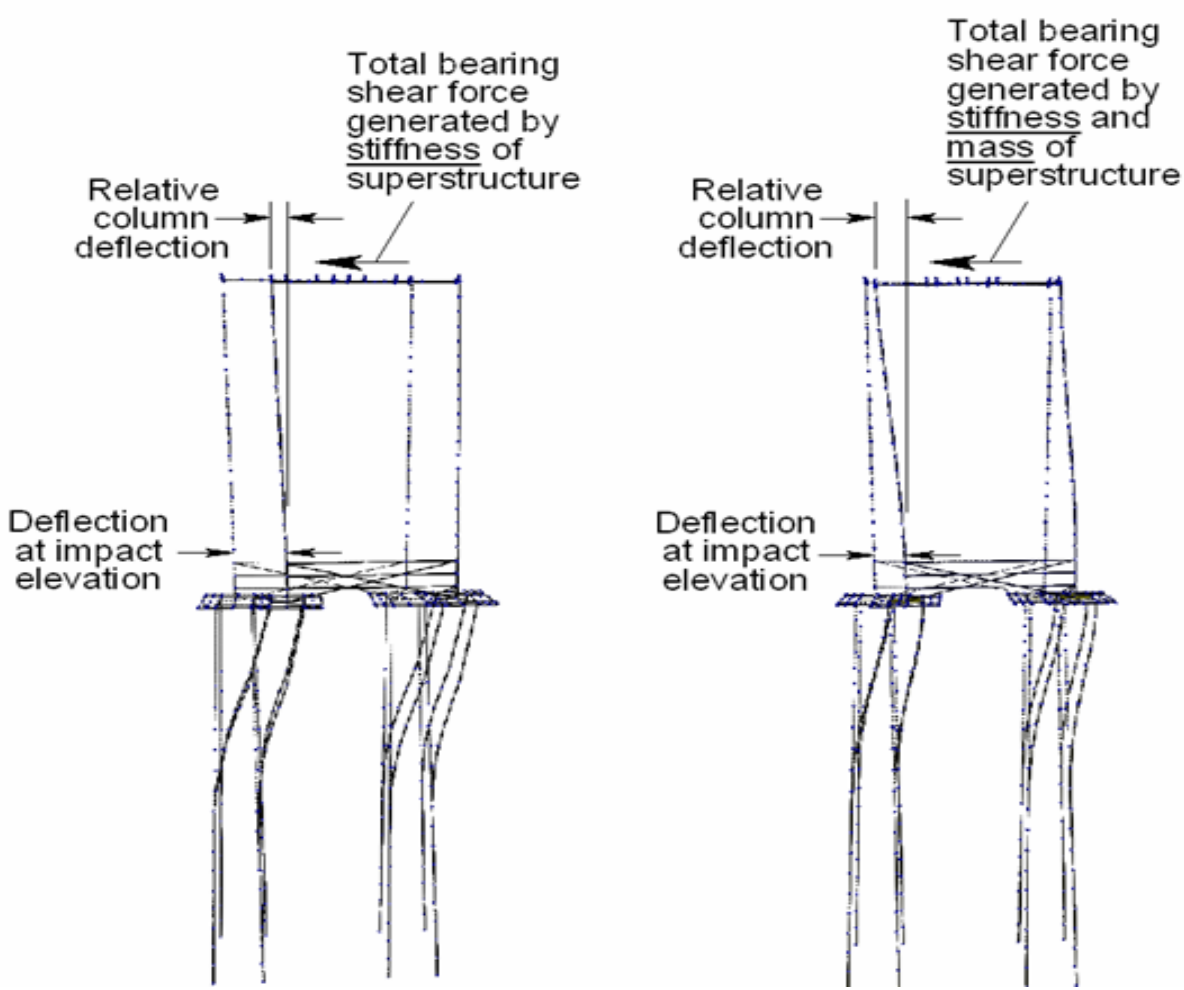
Impact force time history





Courtesy of UF Structure Research Group, Gary Consolazio et al.

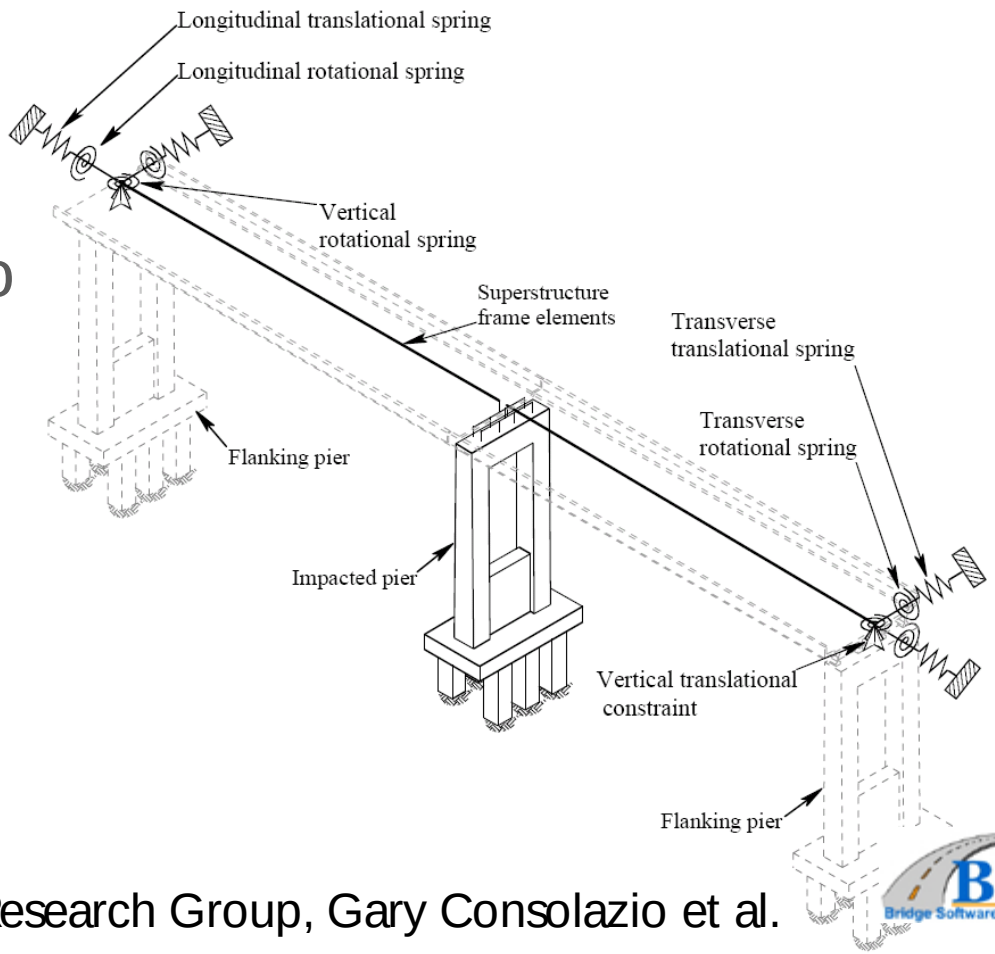
Dynamic Amplification Effects



Courtesy of UF Structure Research Group, Gary Consolazio et al.

Simplified Superstructure Analysis Model

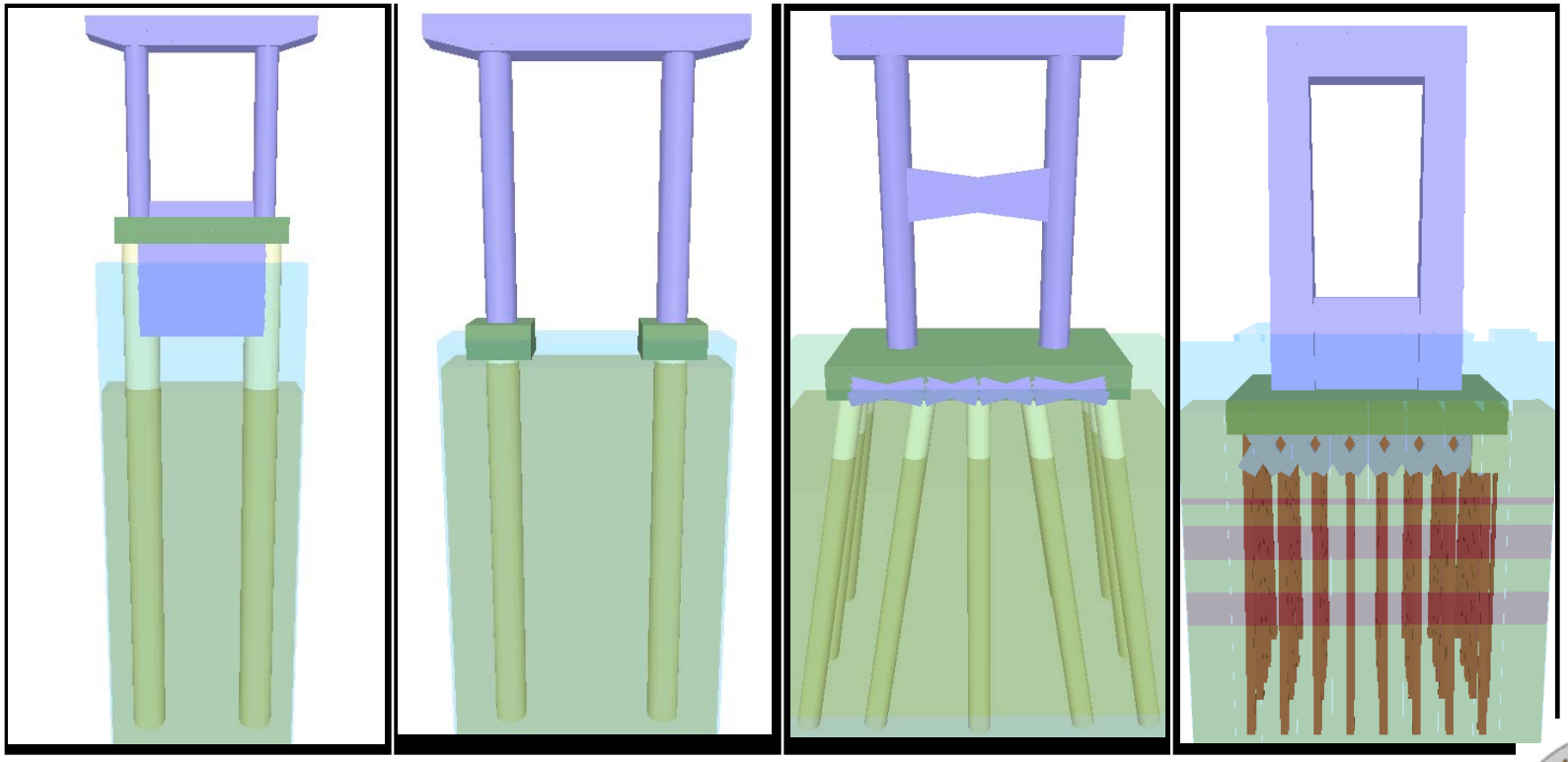
- Full bridge models : computationally expensive
- One-pier two-span (OPTS) model
  - Impacted pier and two adjacent spans are retained
  - Remainder of bridge modeled with springs & point masses



Courtesy of UF Structure Research Group, Gary Consolazio et al.

FB-Multipier Model Development

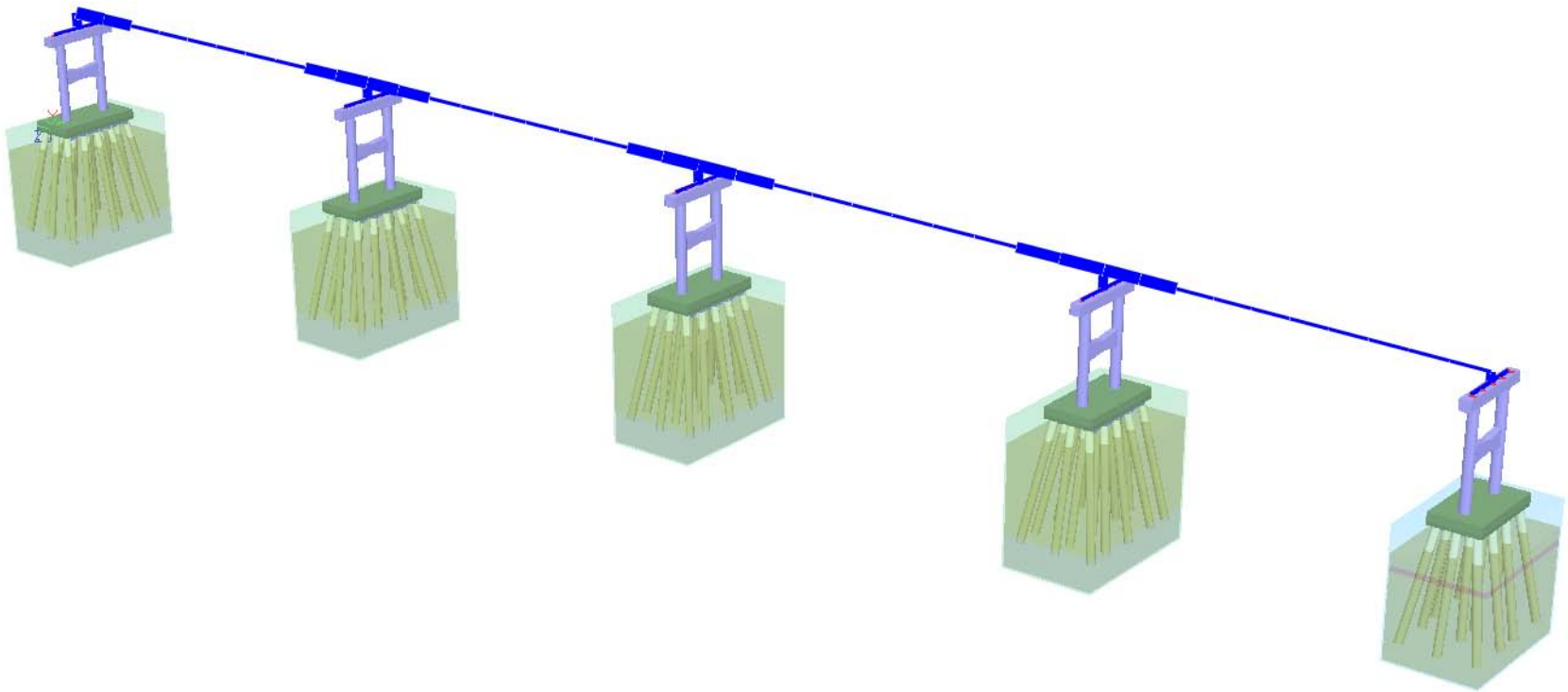
- CVIA and OPTS have been implemented in FB-MultiPier
- Several Florida bridge-configurations are currently being analyzed:



SR-20 at Blountstown channel pier | SR-20 at Blountstown off-channel pier | New St. George Island channel pier | New St. George Island off-channel pier

FB-Multipier Full Bridge Model

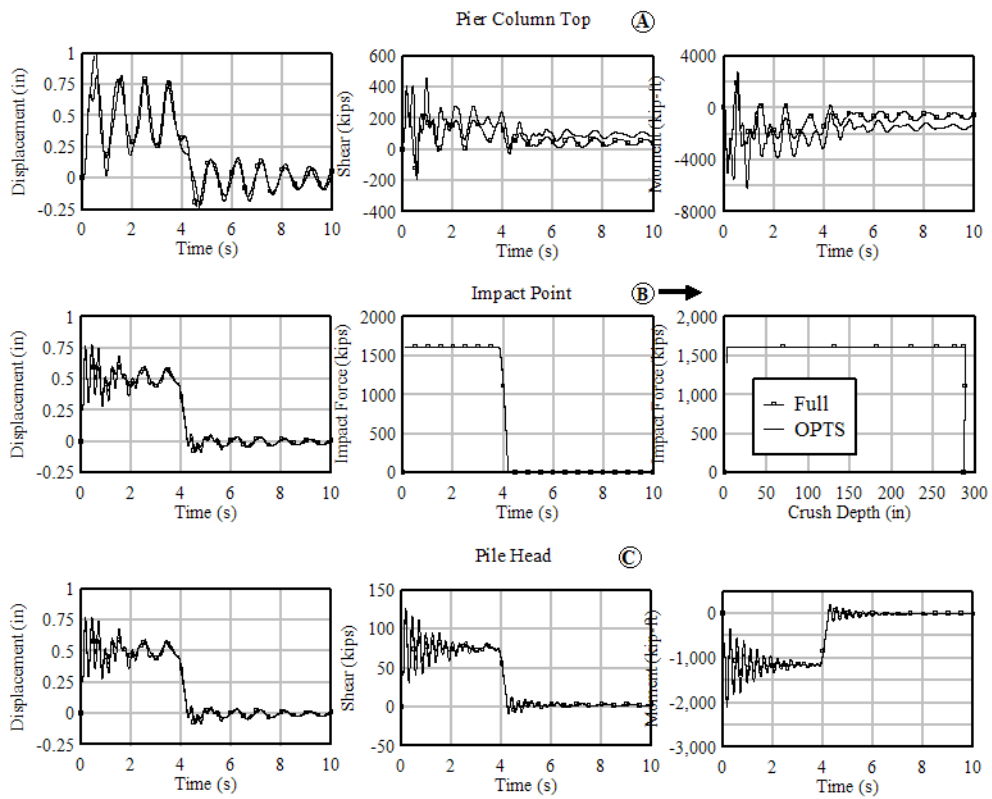
- New St. George Island Bridge (constructed: 2004): Channel pier



Courtesy of UF Structure Research Group, Gary Consolazio et al.

CVIA output: OPTS vs. Full Bridge Analysis

- New St. George Island Bridge (constructed: 2004): Channel pier

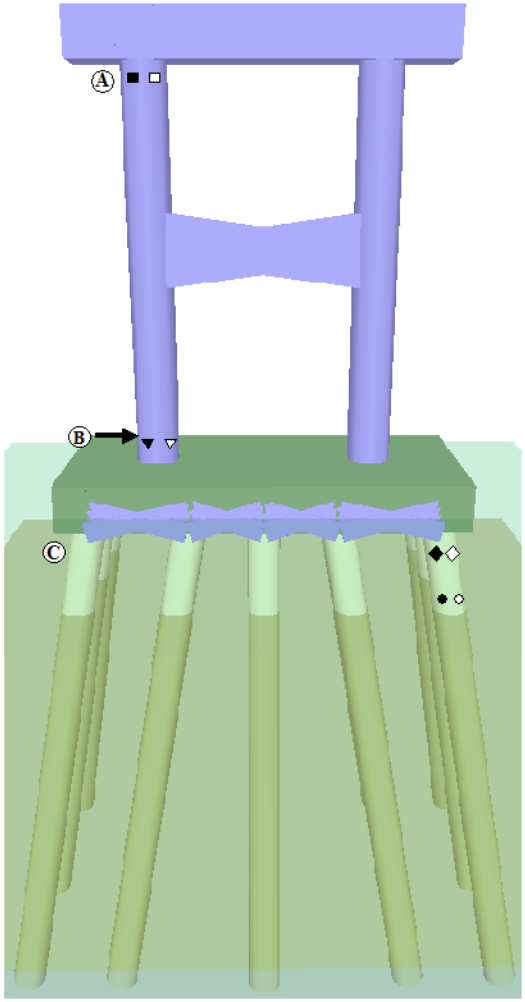


Peak Column Demands:

FULL		OPTS	
▼ Shear:	1670 kips	▽ Shear:	1650 kips
■ Moment:	5419 kip-ft	□ Moment	7074 kip-ft

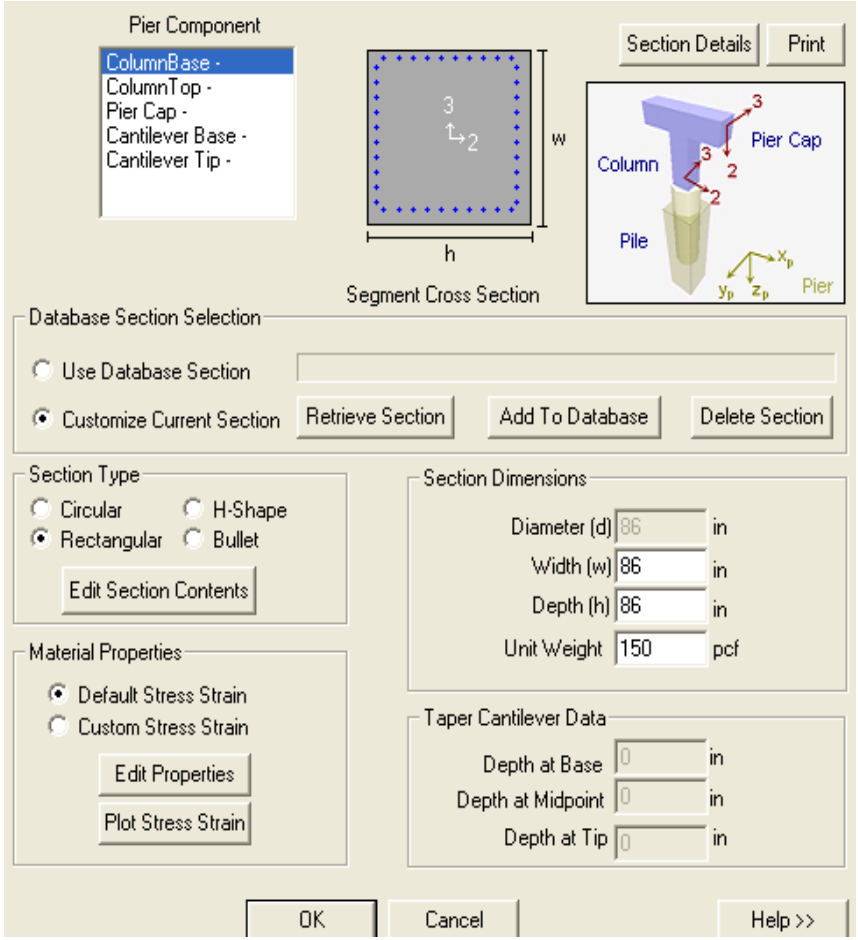
Peak Pile Demands:

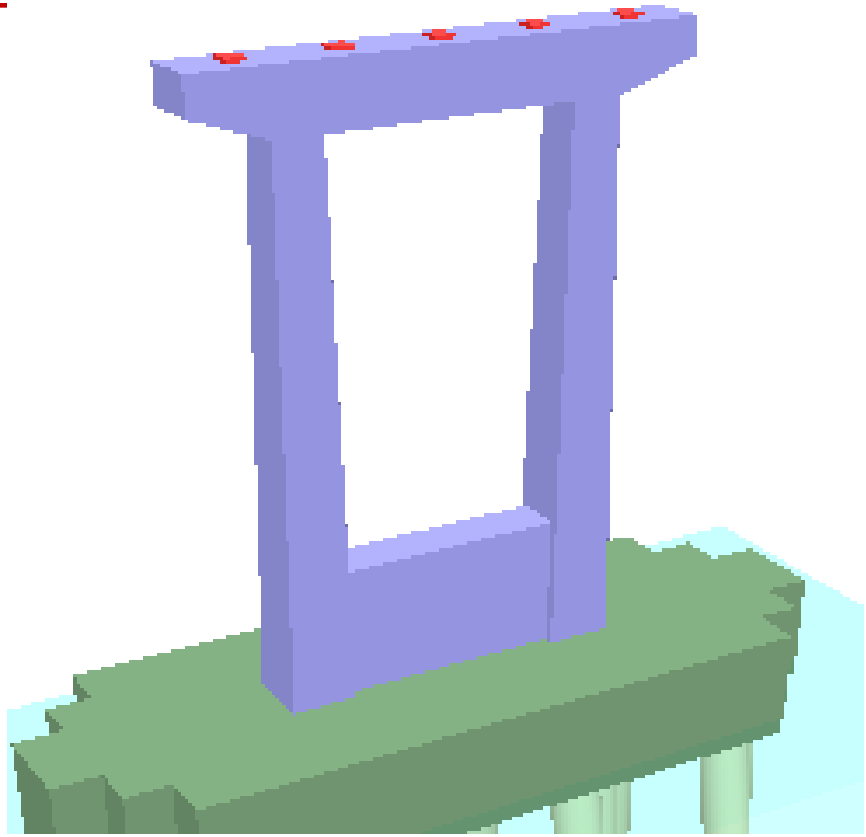
FULL		OPTS	
● Shear:	175.6 kips	○ Shear:	183.0 kips
◆ Moment:	2585 kip-ft	◇ Moment	2698 kip-ft



Design Table Application (Example)

Easy Access to Critical Loadings





Tapered column and cap sections

Display of Axial Member Forces (Text Format)

AXIAL FORCES AT PILE HEADS
(USE TO COMPARE TO PILE DRIVE CAPACITY)
MAXIMUM COMPRESSION AND MAXIMUM TENSION FORCES

"STRENGTH CASES"

PIER	PILE	MAX TENSION	COMB	AASHTO	D/C	MAX COMPRESSION	COMB	AASHTO	D/C
1	1	n/a	n/a	n/a	n/a	-753.46	2	STRENGTH-I	0.42
1	2	n/a	n/a	n/a	n/a	-747.84	21	STRENGTH-V	0.48
1	3	n/a	n/a	n/a	n/a	-752.73	37	STRENGTH-V	0.52
1	4	n/a	n/a	n/a	n/a	-752.76	37	STRENGTH-V	0.47
1	5	n/a	n/a	n/a	n/a	-752.20	35	STRENGTH-V	0.41
1	6	n/a	n/a	n/a	n/a	-743.90	1	STRENGTH-I	0.46
1	7	n/a	n/a	n/a	n/a	-740.50	1	STRENGTH-I	0.44
1	8	n/a	n/a	n/a	n/a	-743.76	1	STRENGTH-I	0.41
1	9	n/a	n/a	n/a	n/a	-738.27	1	STRENGTH-I	0.50
1	10	n/a	n/a	n/a	n/a	-758.53	41	STRENGTH-V	0.40
1	11	n/a	n/a	n/a	n/a	-751.10	25	STRENGTH-V	0.48
1	12	n/a	n/a	n/a	n/a	-747.82	25	STRENGTH-V	0.52
1	13	n/a	n/a	n/a	n/a	-748.10	29	STRENGTH-V	0.49

"SERVICE CASES"

PIER	PILE	MAX TENSION	COMB	AASHTO	D/C	MAX COMPRESSION	COMB	AASHTO	D/C
1	1	n/a	n/a	n/a	n/a	-594.63	99	SERVICE-I	0.12
1	2	n/a	n/a	n/a	n/a	-593.68	85	SERVICE-I	0.14
1	3	n/a	n/a	n/a	n/a	-596.40	85	SERVICE-I	0.11
1	4	n/a	n/a	n/a	n/a	-597.49	101	SERVICE-I	0.15

"EXTREME EVENT II CASES"

PIER	PILE	MAX TENSION	COMB	AASHTO	D/C	MAX COMPRESSION	COMB	AASHTO	D/C
1	1	n/a	n/a	n/a	n/a	-932.30	84	EXTREME-II	0.
1	2	n/a	n/a	n/a	n/a	-846.37	69	EXTREME-II	0.
1	3	n/a	n/a	n/a	n/a	-831.16	73	EXTREME-II	0.
1	4	n/a	n/a	n/a	n/a	-872.56	74	EXTREME-II	0.

Display of Shear Member Forces (Excel Format)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1							**PIER CAP SHEAR DESIGN**								
2							**Maximum Shear Forces at Left and Right of Bearings and at Column Faces**								
3															
4	**"Strength Cases"**														
5															
6	**BEARING**	**ROW**	**LOC.**	**PROP NO.**	**NODE NO.**	**LC**	**AASHTO CASE**	**i OR j**	**F22**	**F33**	**FAX**	**M22**	**M33**	**T**	**D/C**
7															
8	1	1	LEFT	16	495	24	STRENGTH-V	J	-14.86	0.00	0.00	0.00	23.76	0.00	0.00
9	1	1	RIGHT	15	495	2	STRENGTH-I	I	-705.94	0.00	0.00	0.00	22.84	0.00	0.00
10	2	1	LEFT	12	499	2	STRENGTH-I	J	1078.11	0.00	-41.07	-0.01	-1245.06	0.00	0.08
11	2	1	RIGHT	12	499	35	STRENGTH-V	I	389.97	0.00	-42.73	0.00	-864.70	0.00	0.05
12	3	1	LEFT	12	502	2	STRENGTH-I	J	335.84	0.00	-41.07	0.00	-4779.52	0.00	0.32
13	3	1	RIGHT	12	502	2	STRENGTH-I	I	-354.27	0.00	-41.07	0.00	-4779.51	0.00	0.32
14	4	1	LEFT	12	505	31	STRENGTH-V	J	-404.26	0.00	-42.72	0.00	-723.93	0.00	0.04
15	4	1	RIGHT	12	505	1	STRENGTH-I	I	-1001.87	0.00	-38.43	0.00	-1176.35	0.00	0.08
16	5	1	LEFT	21	520	2	STRENGTH-I	J	10.73	0.00	0.00	0.00	4.04	0.00	0.00
17	5	1	RIGHT	22	520	1	STRENGTH-I	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18															
19	**"Service Cases"**														
20															
21	**BEARING**	**ROW**	**LOC.**	**PROP NO.**	**NODE NO.**	**LC**	**AASHTO CASE**	**i OR j**	**F22**	**F33**	**FAX**	**M22**	**M33**	**T**	**D/C**
22															
23	1	1	LEFT	16	495	85	SERVICE-I	J	-12.71	0.00	0.00	0.00	19.24	0.00	0.00
24	1	1	RIGHT	15	495	99	SERVICE-I	I	-509.87	0.00	7.82	0.00	18.93	0.00	0.00
25	2	1	LEFT	12	499	99	SERVICE-I	J	798.23	0.00	-41.52	0.00	-661.99	0.00	0.04
26	2	1	RIGHT	12	499	99	SERVICE-I	I	309.27	0.00	-33.71	0.00	-662.42	0.00	0.04
27	3	1	LEFT	12	502	99	SERVICE-I	J	257.97	0.00	-33.71	0.00	-3454.74	0.00	0.23
28	3	1	RIGHT	12	502	95	SERVICE-I	I	-268.57	0.00	-33.71	0.00	-3454.62	0.00	
29	4	1	LEFT	12	505	95	SERVICE-I	J	-319.87	0.00	-33.71	0.00	-557.98	0.00	
30	4	1	RIGHT	12	505	93	SERVICE-I	I	-758.17	0.00	-40.01	0.00	-623.30	0.00	
31	5	1	LEFT	21	520	92	SERVICE-I	J	5.62	0.00	0.00	0.00	4.08	0.00	0.00
32	5	1	RIGHT	22	520	85	SERVICE-I	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Example 2: Interconnecting Data, Tools and the Net

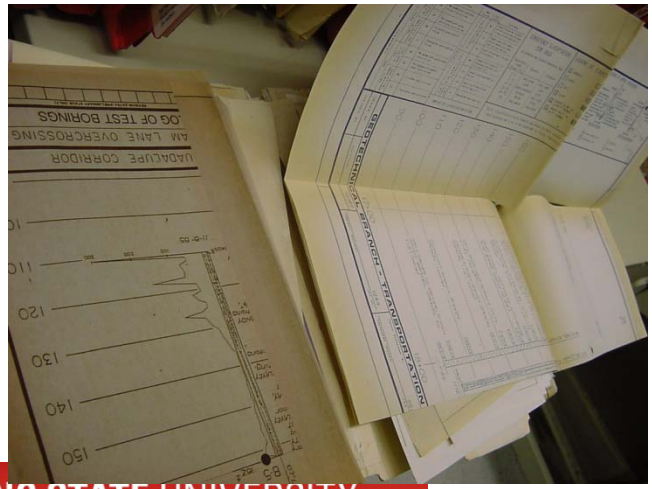
- Data Interchange for Geotechnical and GeoEnvironmental Specialists (DIGGS)
- Incorporating new IT into the Civil Engineering process
  - Shared data
  - Data reuse
  - Web services
  - Business process change

Motivation

- Need to efficiently deliver information from various and distributed resources
- Recognize the cost of site investigations, preserve assets through proper management and storage of data and documents
- Current paper-based systems are inefficient in today's environment
- Current distributed, disconnected and inconsistent electronic systems increase confusion

Caltrans Experience

- **30,000 project files**
- **2 million documents**
- **300 projects/year**
- **80 years of data**
- **Difficult to access information**



Ohio DOT Experience

- **20-30 person hours per week to retrieve information**

Projects or Experienced Cost Savings

- Ohio DOT:
  - 10-20% less drilling, savings $12-24M per year
- Florida DOT:
  - Fewer borings saving $250,000 - $500,000 on one project
- Missouri DOT:
  - 10-15% fewer borings per bridge
- Missouri DOT:
  - $81,000 savings per year in boring log preparation by using electronic data entry in the field
- California DOT:
  - 20% savings ($200k/year) with laboratory data management system implementation

Single Data Entry - Single Organization

Data is collected in the field electronically

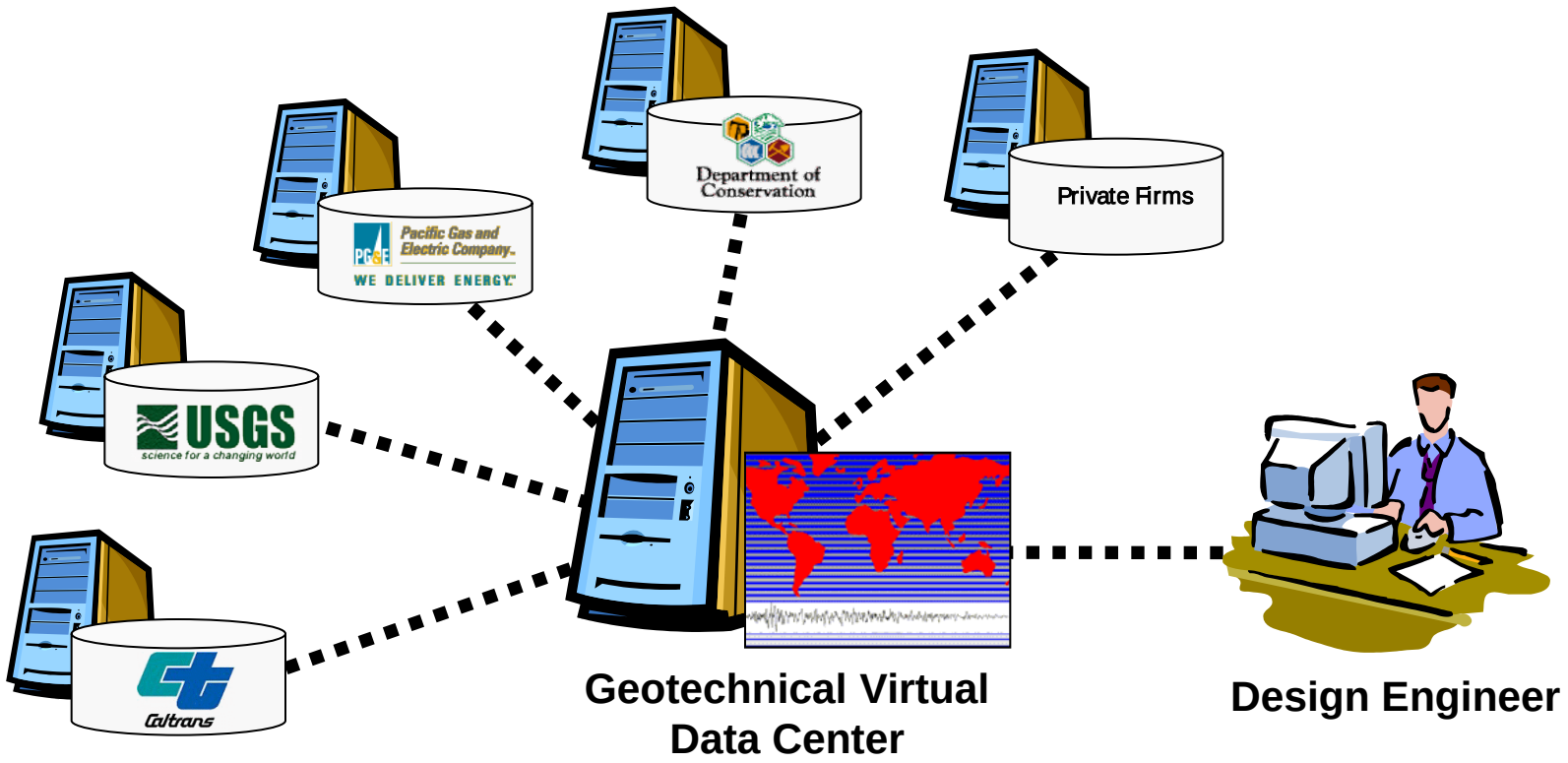
Data files are transferred to a central repository

Design Engineer

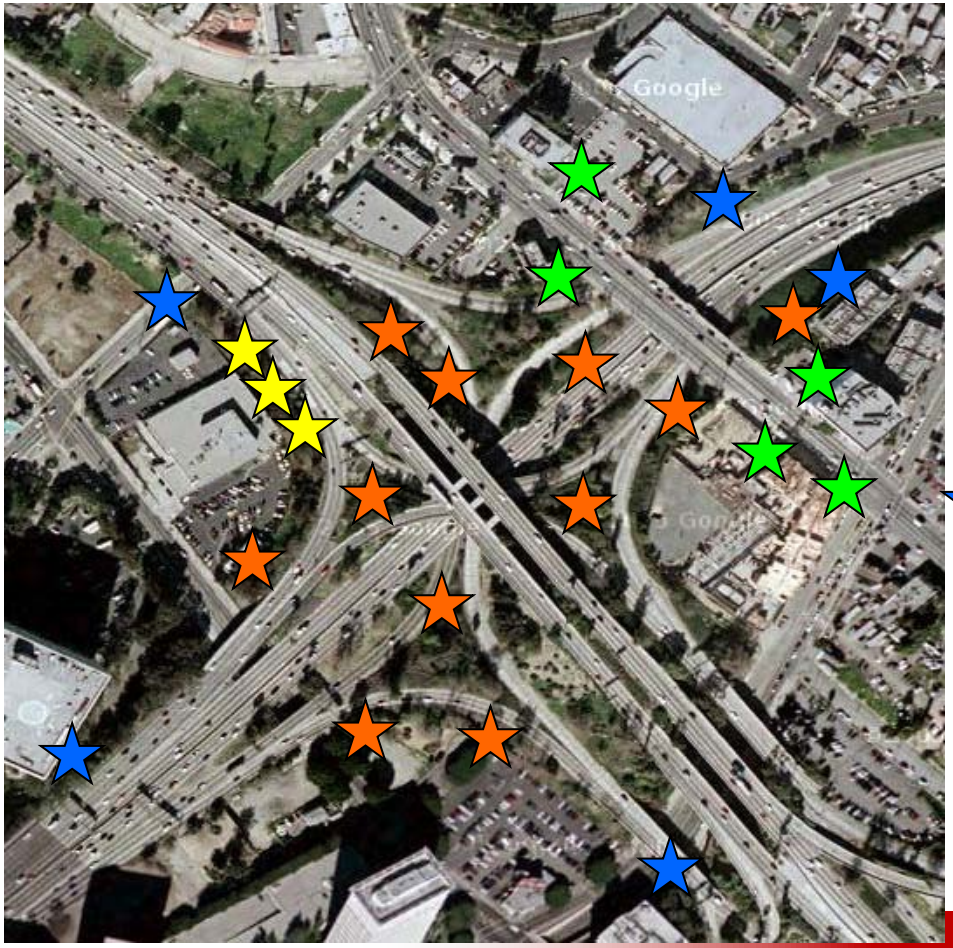
Drafter

Other Staff

Single Data Entry - Multiple Organizations



Example of Multiple Organization Collaboration



Pooled Fund Project TPF-5(111)

- DIGGS Project:
  - Develop a single international data exchange standard
  - Combine existing geotechnical data interchange standards (AGS, COSMOS, FDOT/UF, EPA)
  - Expand to include other data (i.e. geohazards, geotechnical assets)
  - Survey state DOTs and others
  - Finalize standards

Characteristics of DIGGS

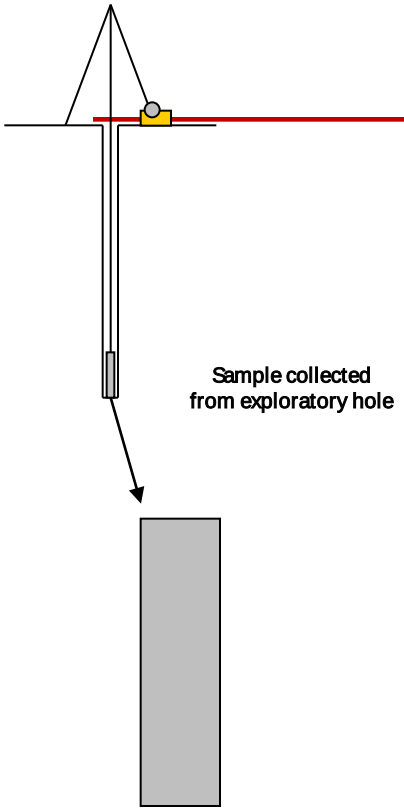
- XML Schema Definition (XSD)
  - Normative document
  - Defines elements
- Standard for internet data transfer
  - Platform independent
  - Tools available for validating, querying, processing, displaying, and transforming
- Compliant with Geography Markup Language (GML)
  - Allows for processing by GIS applications
  - Allows for display of data over the Internet using web services

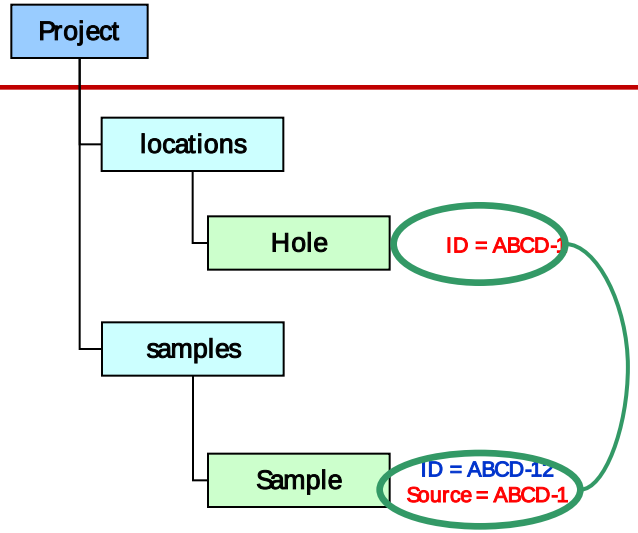
Characteristics of DIGGS

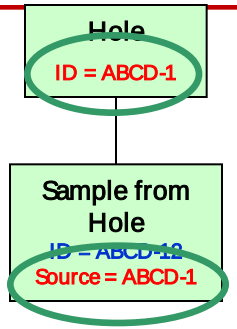
- DIGGS provides a context for different kinds of data that may be related administratively or spatially
- Transfers data commonly reported as part of a geotechnical investigation
  - Borehole records
  - In-situ test data
  - Monitoring data
  - Laboratory test summaries
  - Geophysical data
  - Geoenvironmental data
  - Pile design, installation, and testing data

Example 1 – Sample Taken from an Exploratory Hole

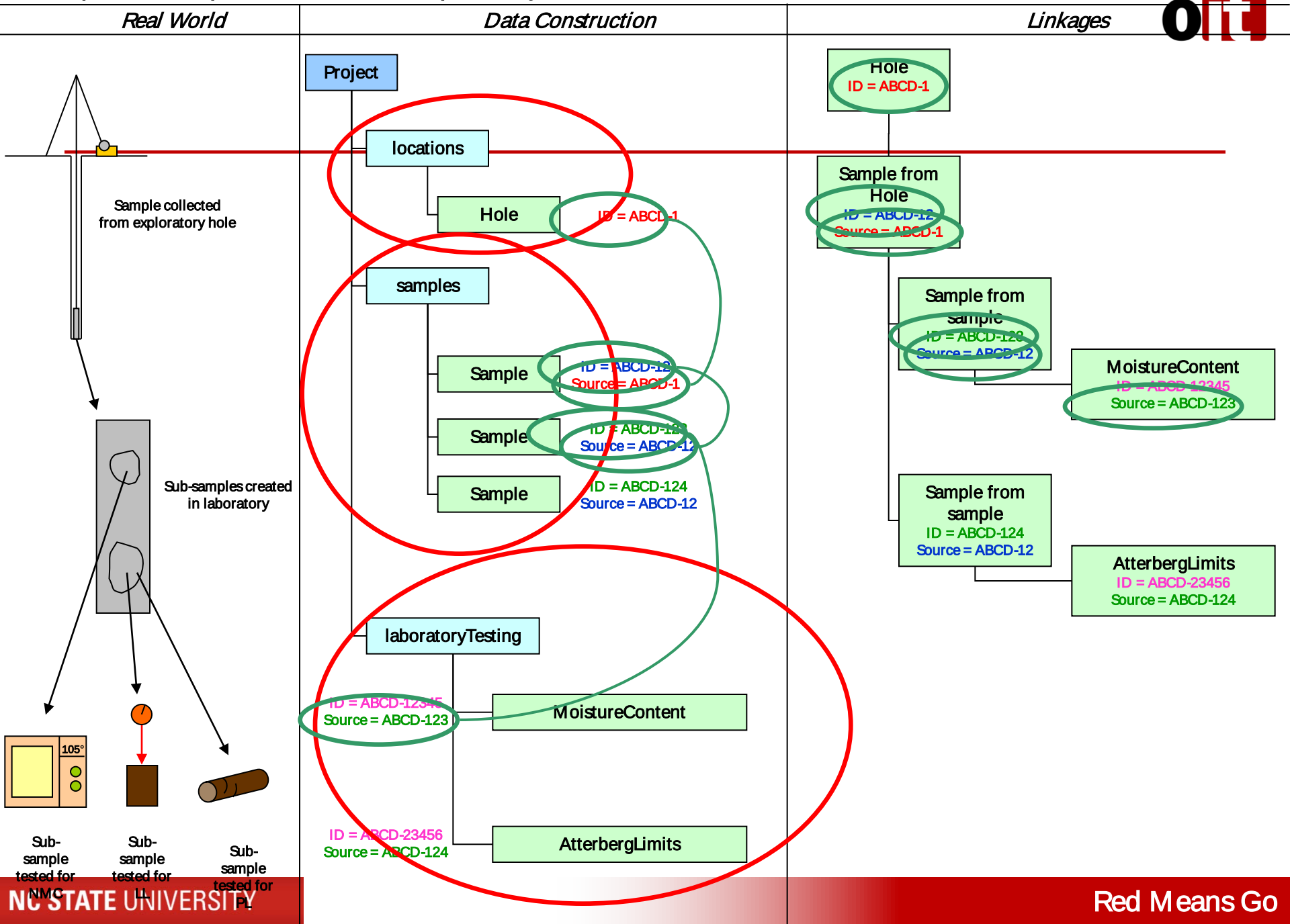
Real World | *Data Construction* | *Linkages*





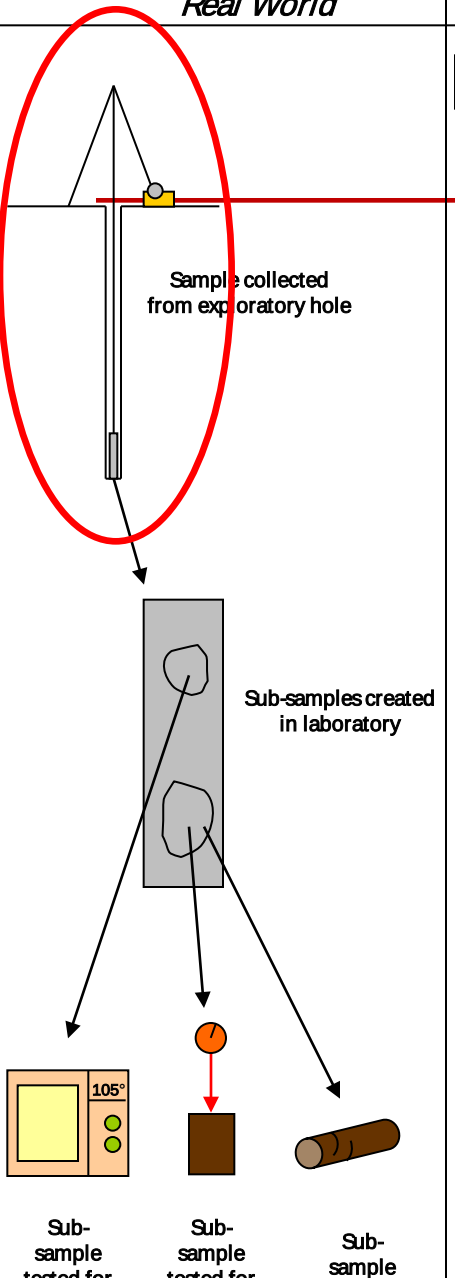


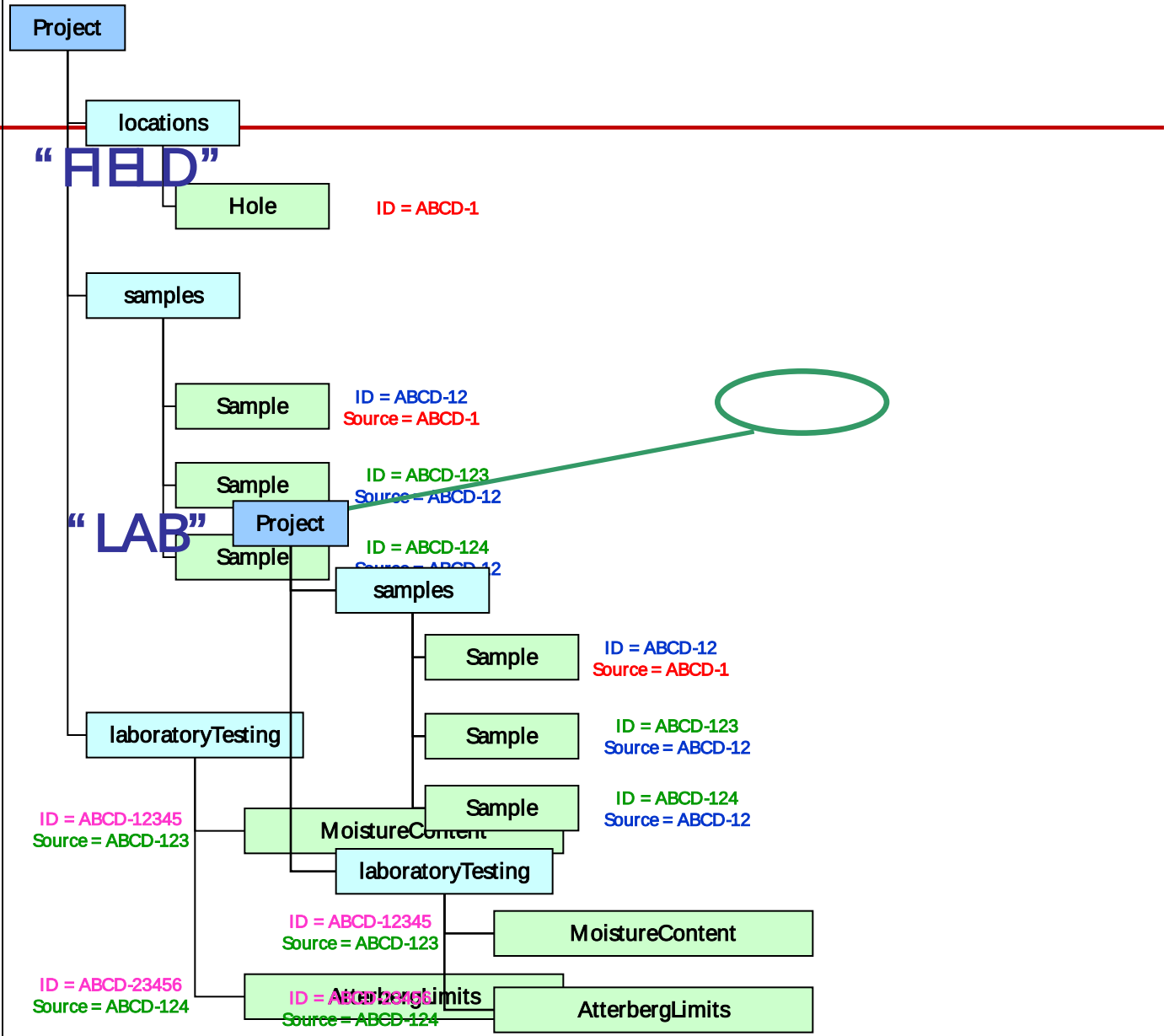
Example 2 – Sample Taken from an Exploratory Hole, tested for NMC, LL and PL



Example 2 – Sample Taken from an Exploratory Hole, tested for NMC, LL and PL

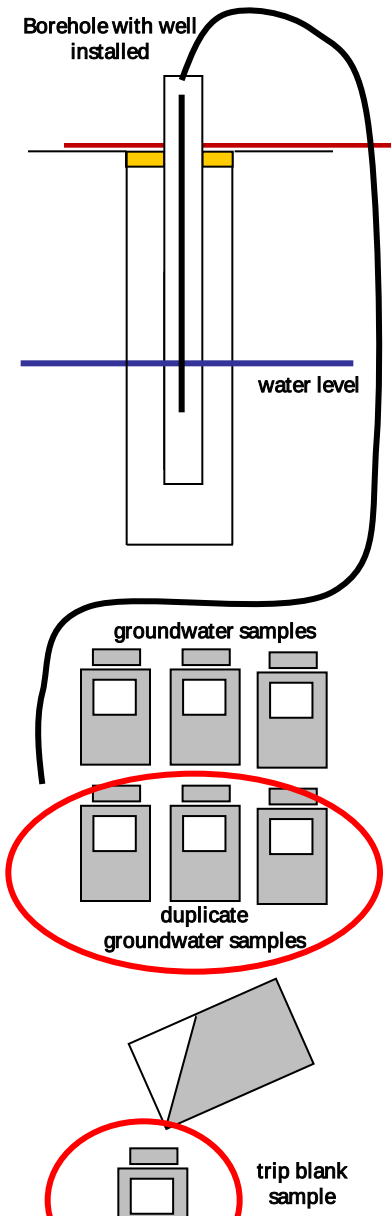
Real World | *Data Construction*

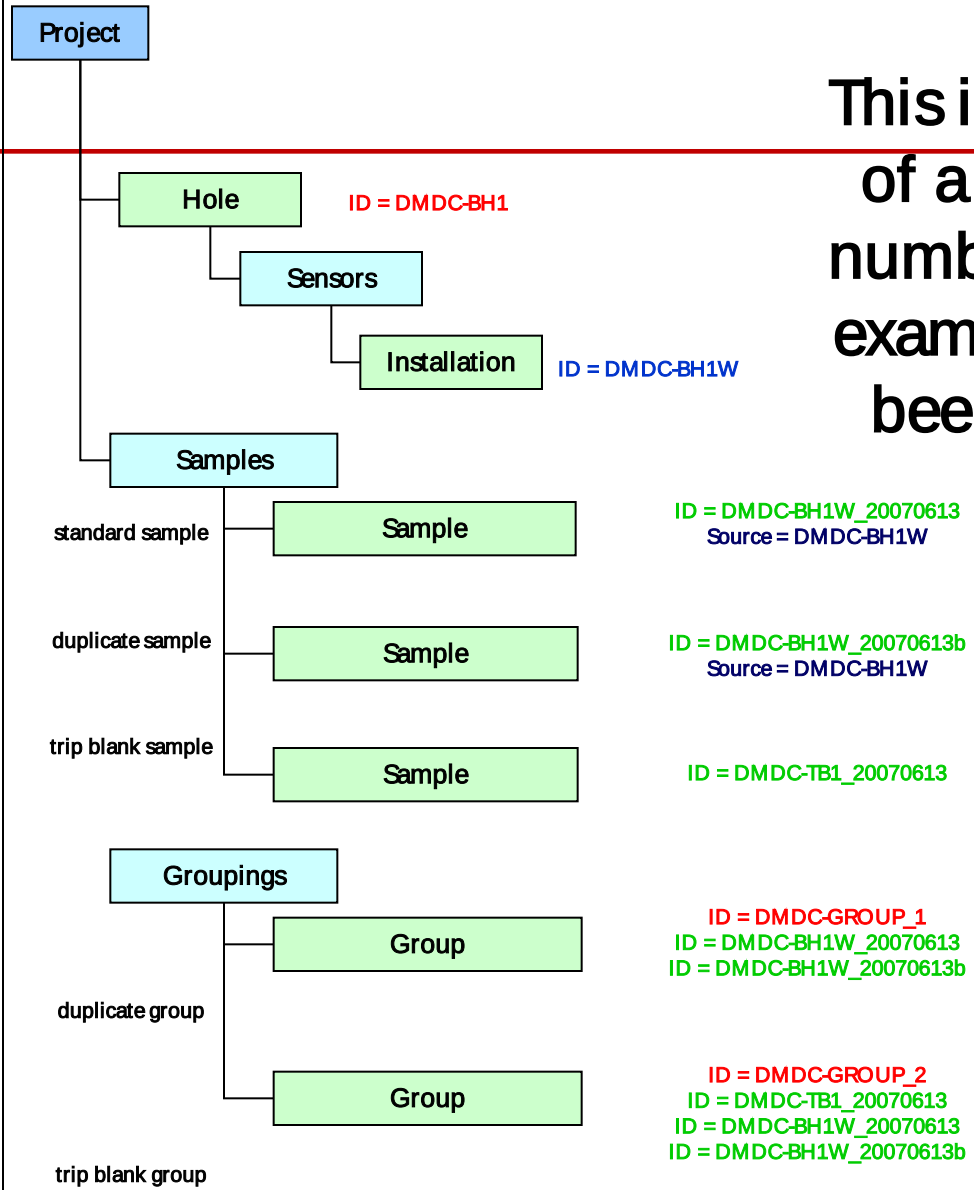




Example 7 – Geoenvironmental: Field Quality Control Samples

Real World | *Data Construction*





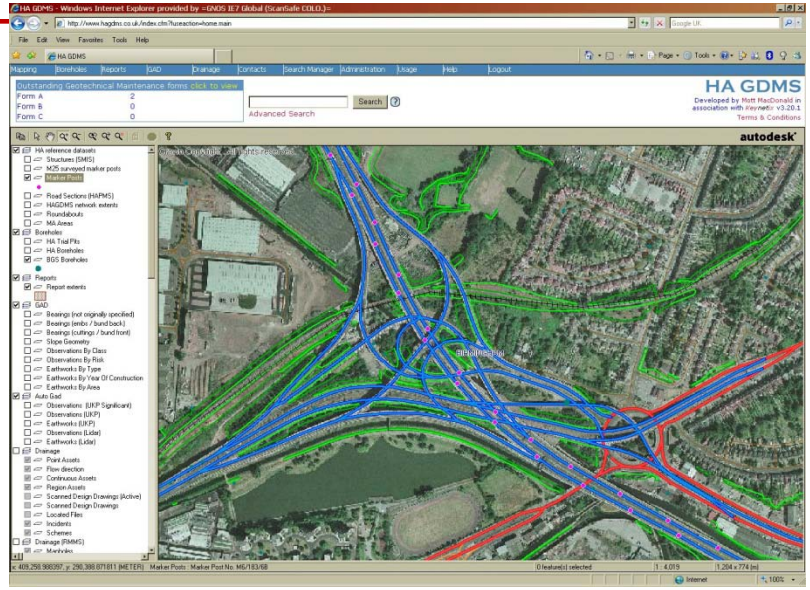
This is one example of a considerable number of complex examples that have been considered

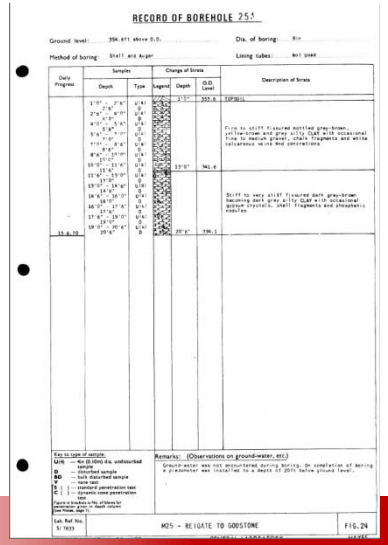
Supporters/Promoters of DIGGS

- The United States Federal Highways Administration
- The United Kingdom Highways Agency
- US Departments of Transportation (CA, CT, FL, GA, IN, KS, KY, MN, MO, NC, OH, TN)
- The United States Geological Survey
- The United States Army Corps of Engineers
- The United States Environmental Protection Agency
- CIRIA (the UK Construction Industry Research and Information Association)
- AGS (the UK Association of Geotechnical and Geoenvironmental Specialists)
- COSMOS (Consortium of Organizations for Strong-Motion Observation Systems)
- The University of Florida

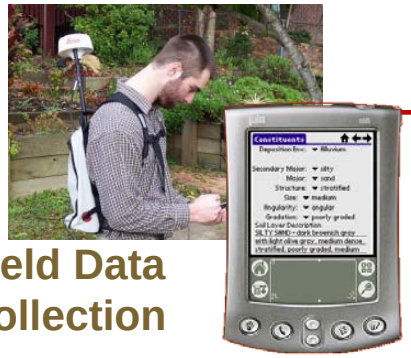
HA (UK) Geotechnical Data Management System (HA GDMS)

- Internet-based GIS
- Stores data on:
  - spatial context (mapping and aerial photos)
  - assets
  - reports
  - boreholes
- Supports UK AGS data transfer format
  - data storage/retrieval
  - summary logs
  - summary test sheets



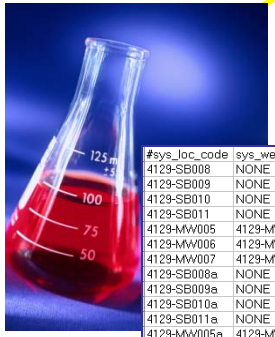


EarthSoft – Equis Database



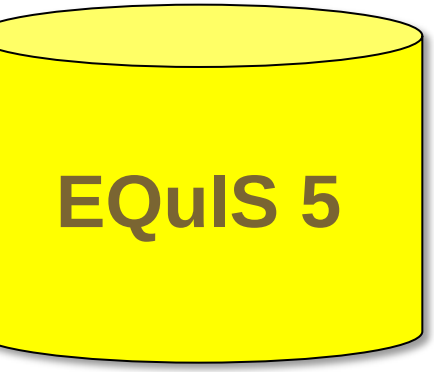
Field Data Collection

Monitoring/ Instrumentation

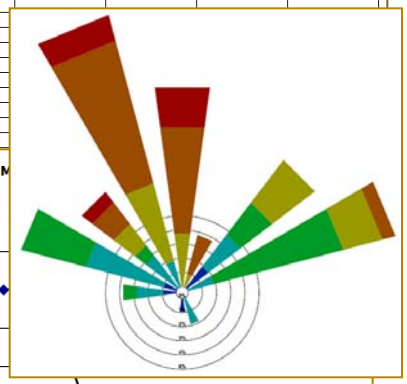


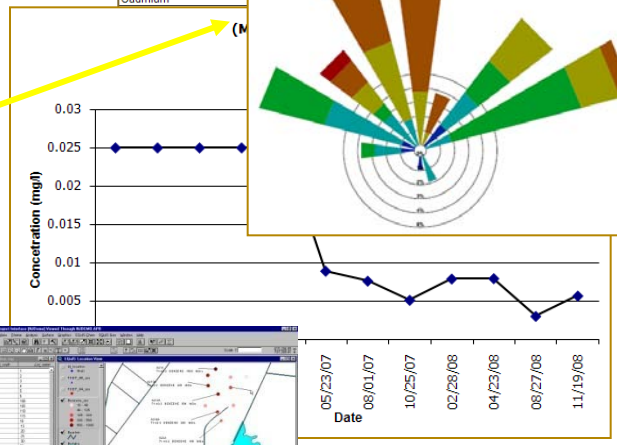
#sys_loc_code	sys_well_code	X_coord	Y_coord
4129-SB008	NONE	620071.4941	3339792.757
4129-SB009	NONE	620085.495	3339809.48
4129-SB010	NONE	619666.5208	3339949.574
4129-SB011	NONE	619505.707	3339908.768
4129-MW005	4129-MW005	619443.7651	3339953.166
4129-MW006	4129-MW006	620133.2989	3340195.292
4129-MW007	4129-MW007	620162.5517	3340127.655
4129-SB008a	NONE	620071.4941	3339792.757
4129-SB009a	NONE	620085.495	3339809.48
4129-SB010a	NONE	619666.5208	3339949.574
4129-SB011a	NONE	619505.707	3339908.768
4129-MW005a	4129-MW005	619443.7651	3339953.166
4129-MW006a	4129-MW006	620133.2989	3340195.292
4129-MW007a	4129-MW007	620162.5517	3340127.655

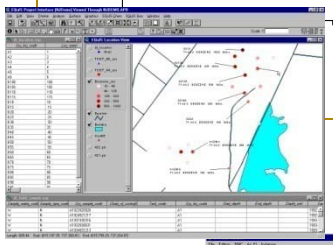
Laboratory EDDs

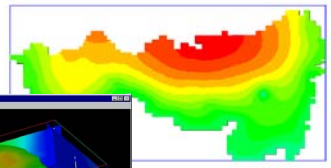


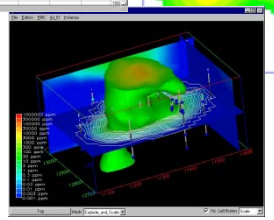
Barrick Bald Mountain Mines Inc.				
Sample Location:	BMM Well - 1			
Location Code:	Well-1			
Reporting Period:	4th Qtr. 2008			
Permit No.:	NEV50045			
		1st Qtr.	2nd Qtr.	3rd Qtr.
Lab Name:		SVL	SVL	SVL
Lab Reference No.:		C08020752	W803113	W810224
Sample Date:		02/19/2008	06/11/2008	09/15/2008
Lab Test Date:		02/19/2008	06/11/2008	09/15/2008
Sampled By:		Nick/Tina	Treyn	Tina/Amand
Constituent				
Aluminum				
Antimony				
Arsenic				
Barium				
Beryllium				
Bicarbonate				
Boron				
Cadmium				







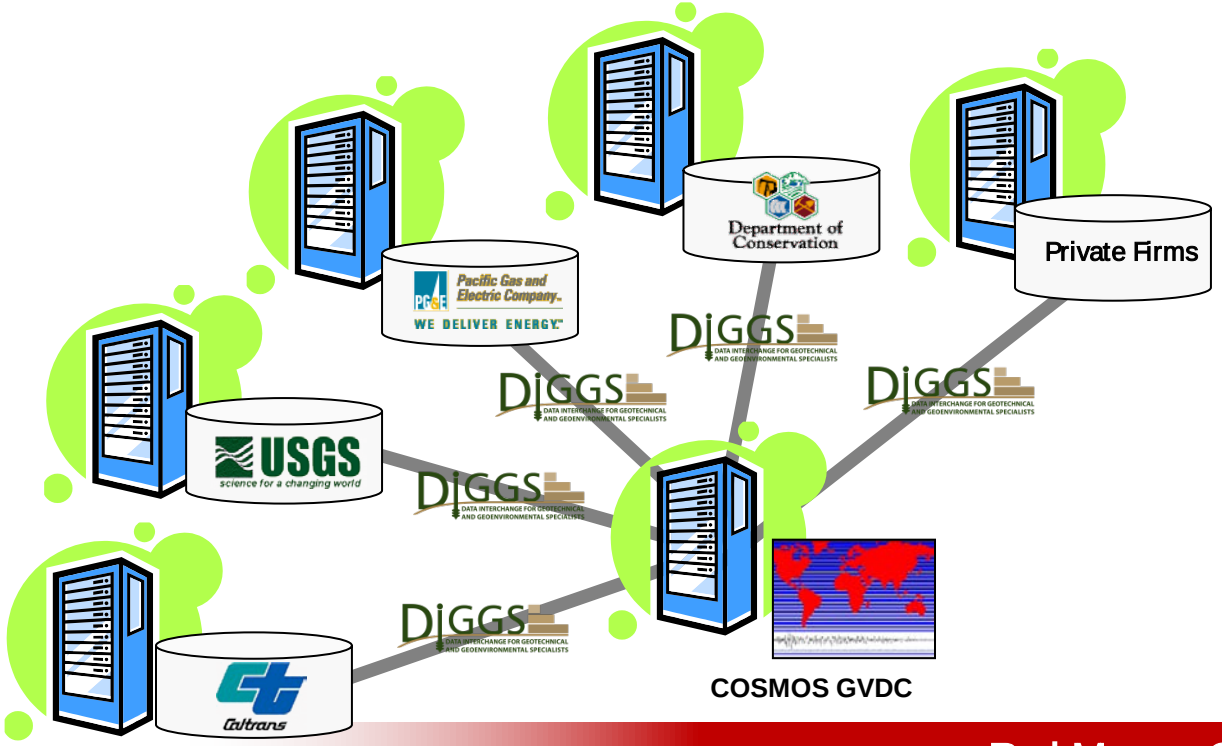




Data In, Information Out

Geotechnical Virtual Data Center

- Virtual gateway to data repositories from multiple agencies.
- Uses DIGGS for standardized data exchange



DIGGS
DATA INTERCHANGE FOR GEOTECHNICAL AND GEOENVIRONMENTAL SPECIALISTS

COSMOS /PEER-LL - Mozilla Firefox

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COSMOS/PEER-LL

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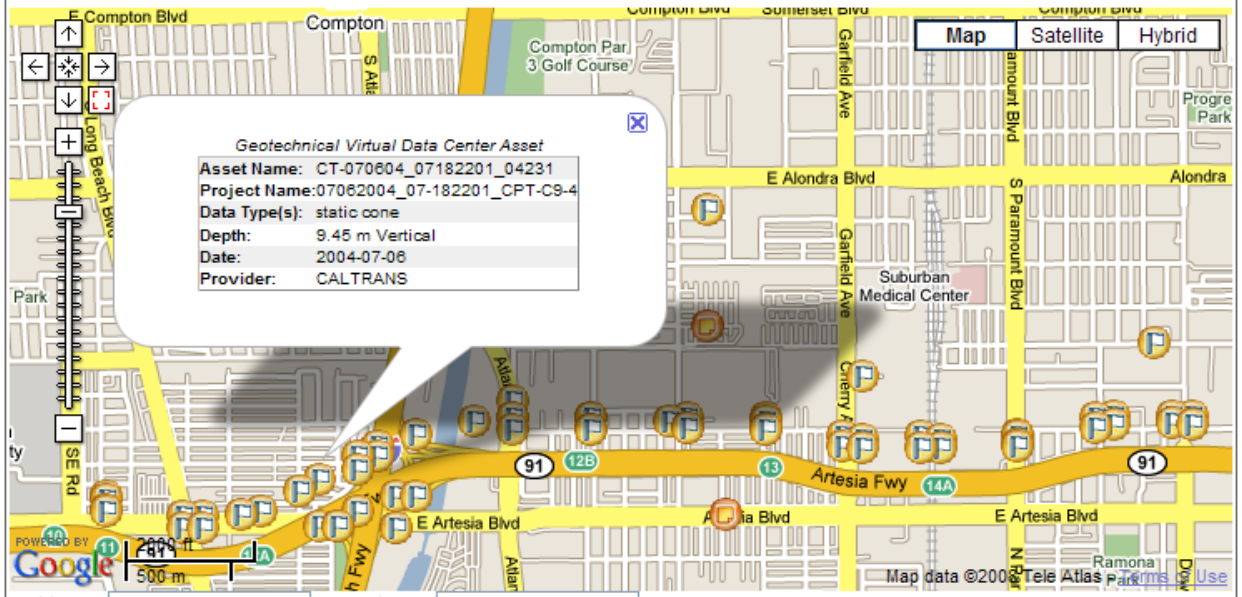
Document Search

Use this page to search our database of geotechnical documentation.



Geotechnical Virtual Data Center Asset

Asset Name:	CT-070604_07182201_04231
Project Name:	07062004_07-182201_CPT-C9-4
Data Type(s):	static cone
Depth:	9.45 m Vertical
Date:	2004-07-06
Provider:	CALTRANS

Latitude: -118.15323829650879 Longitude: 33.8767579211837

Search

Provider - All Providers - Project Date(mm/dd/yyyy) from to

Asset Name Project Name Borehole Depths min max

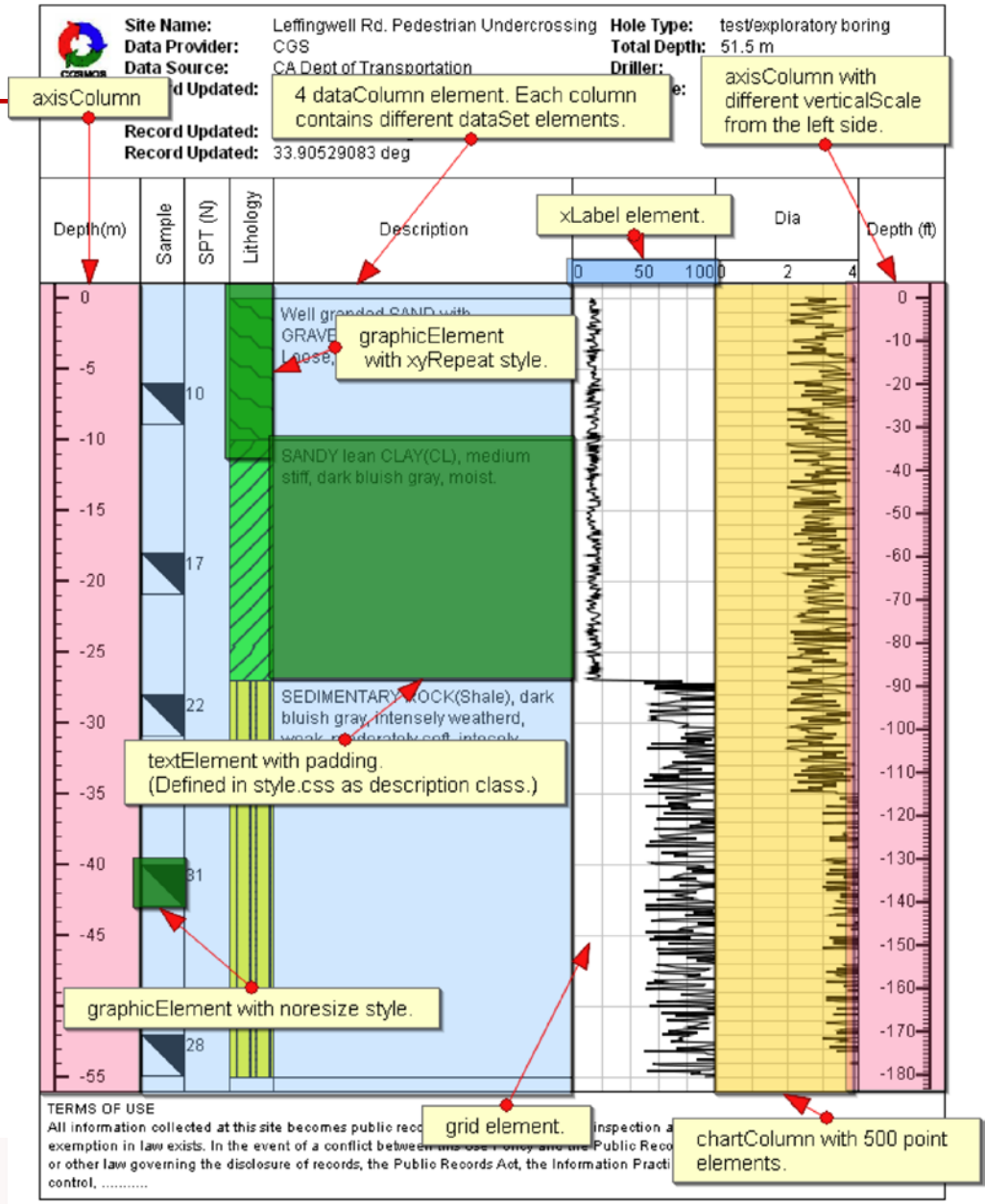
Boundaries (decimal degrees) Longitude min Longitude max Latitude min Latitude max

Search for Selected Data Types All Checked by Default

Results Per Page 60 search

Borehole Previewer

- Viewer xsl, css, and javascript completed
- Viewer Application (in development)
  - DIGGS xml ->XSLT -> CosmosLog xml
  - Possible user-customized vertical scale
  - Other user-customizations possible but not planned



Summary

- Need to take advantage of technology trends and improve research innovation, teaching & learning, and professional practice
- Partner, partner, partner
- Educate for the “smile”
  - Creativity
  - Higher end of Bloom’s Taxonomy

"Our Age of Anxiety is, in great part, the result of trying to do today's jobs with yesterday's tools."

~Marshall McLuhan~