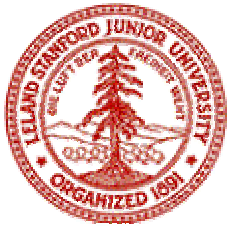


Stanford University
Engineering Informatics Group (http://eil.stanford.edu)

Composition of Engineering Web Services

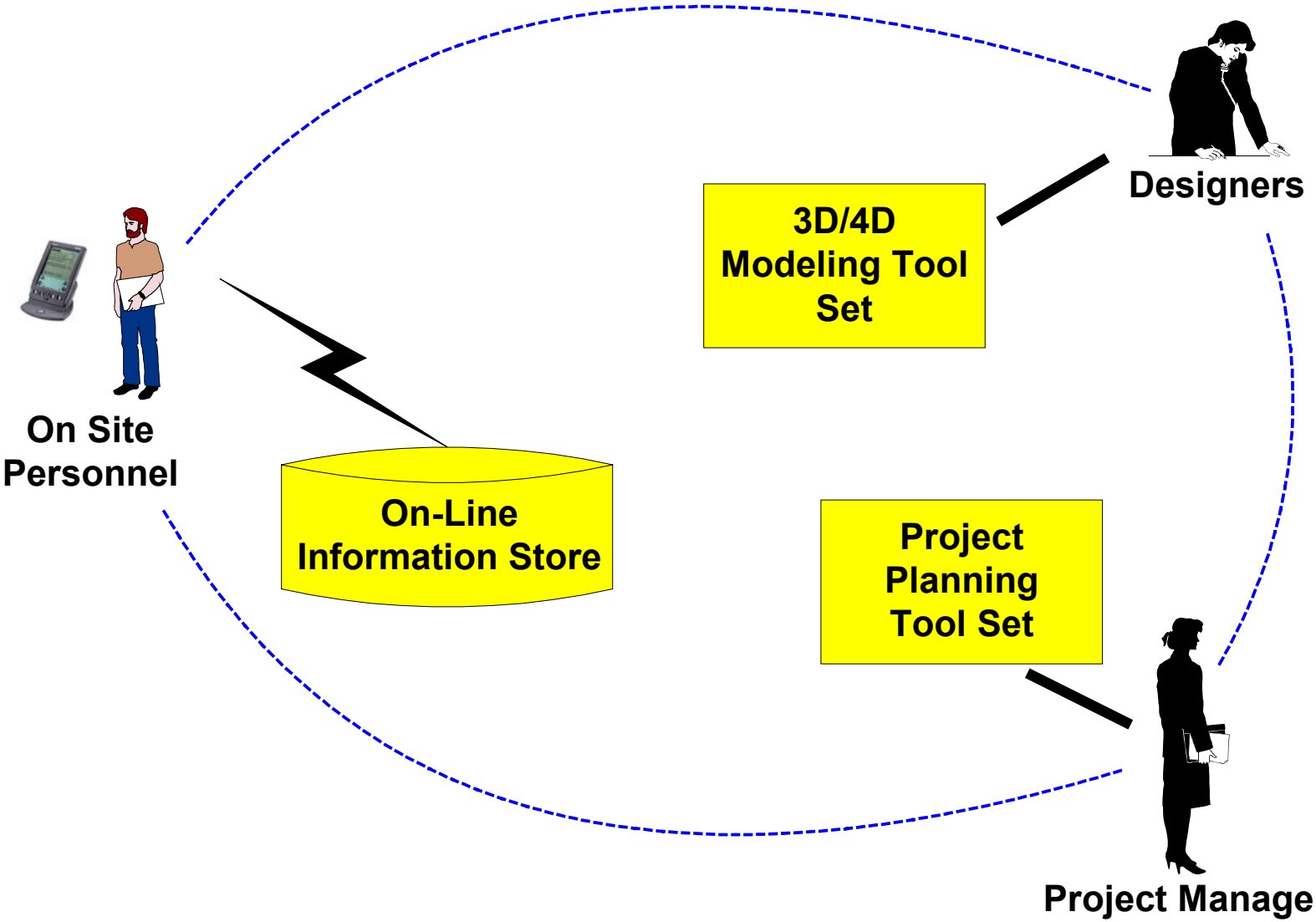
David Liu	Department of Electrical Engineering
Jim Cheng	Department of Civil and Environmental Engineering
Jun Peng	Department of Civil and Environmental Engineering
Kincho Law	Department of Civil and Environmental Engineering
Gio Wiederhold	Computer Science Department

Agenda

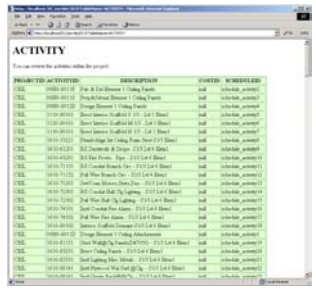
- **Ubiquitous Computing Environment**
- **Service Integration – FICAS**

Ubiquitous Computing Environment

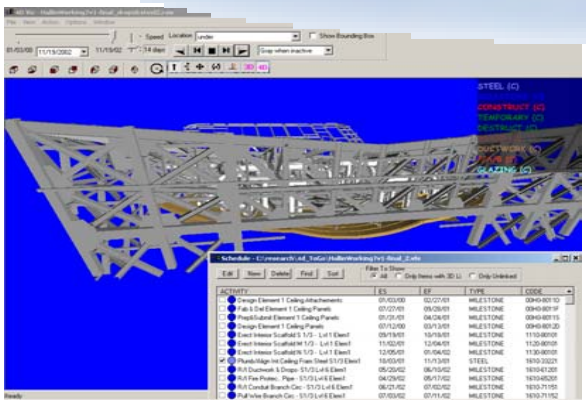
Ubiquitous Computing – An AEC Scenario

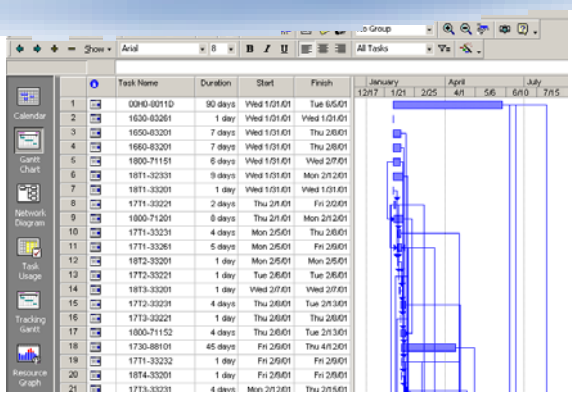


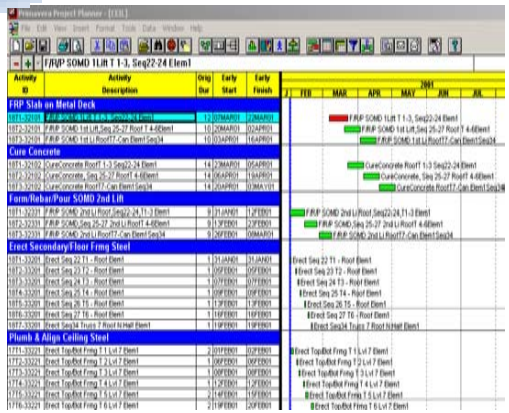
Distributed Engineering Service and Integration



Mediators (Content and Access)
Information Exchange (DBMS, PSL, IFC, XML)
Service Integration (FICAS)

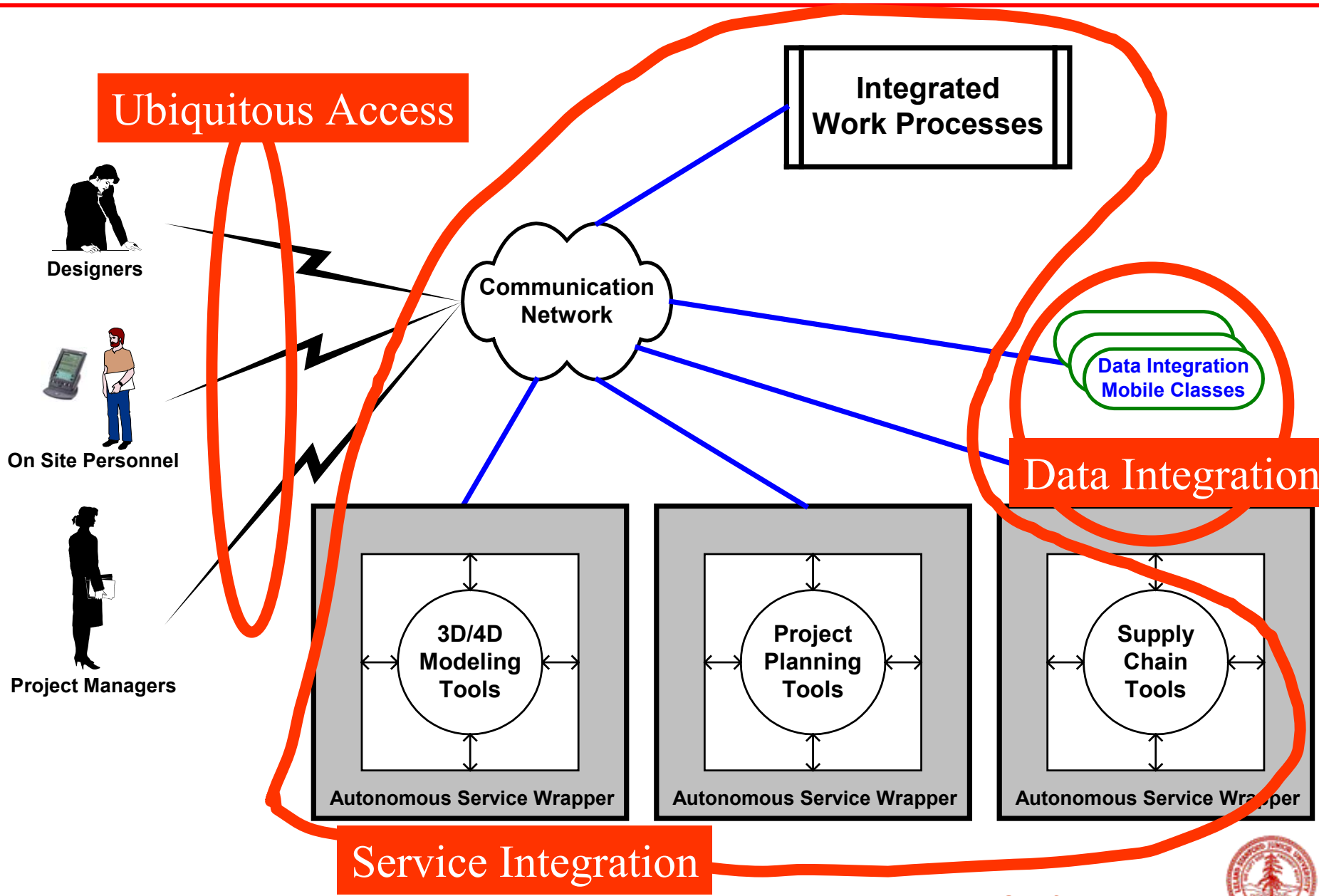






Engineering Application Services

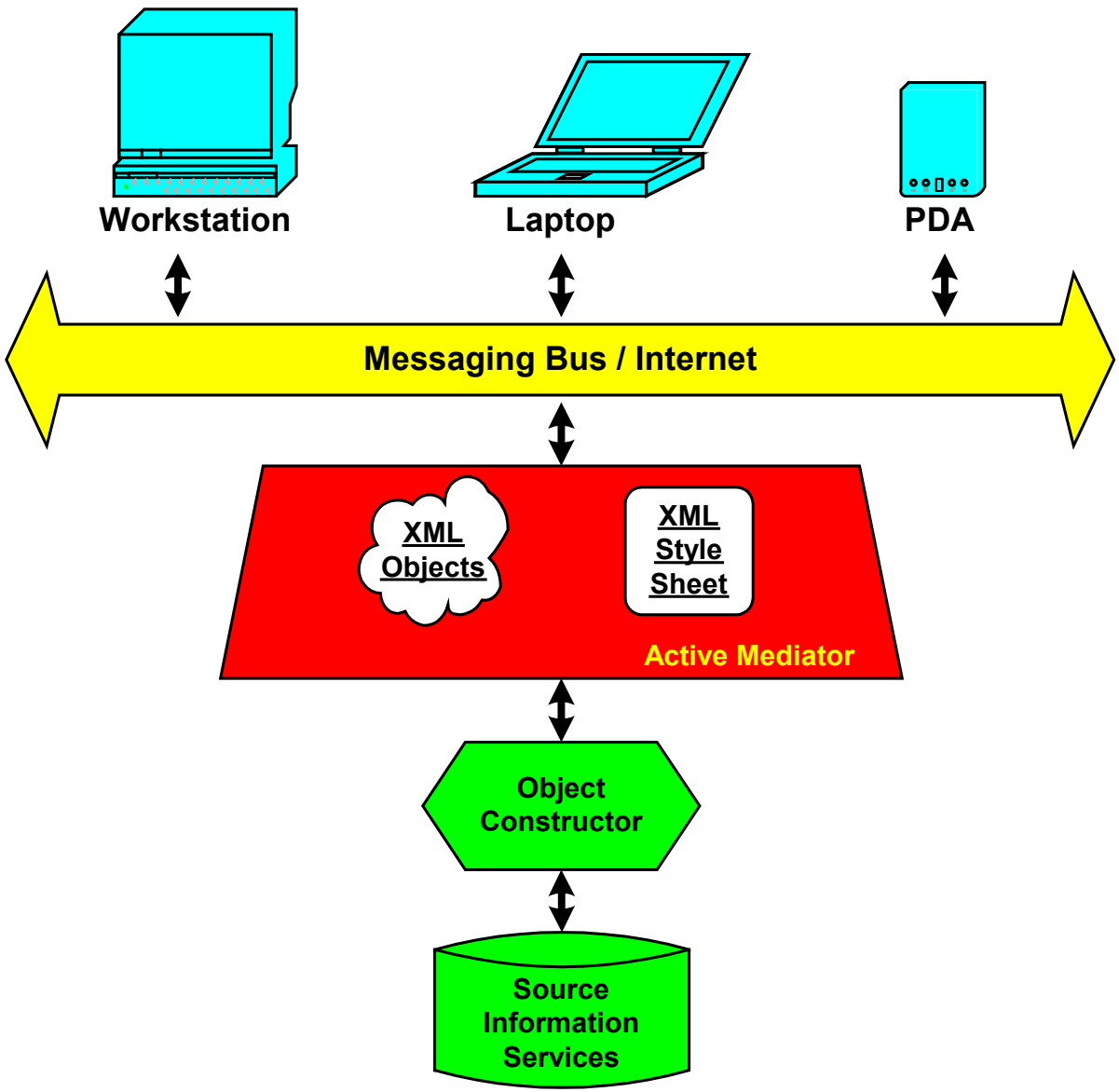
An Integrated Service Environment



Ubiquitous Computing Environment – Three Issues

- **Ubiquitous Access**
  - Wireless Network Infrastructure
  - Wireless Devices
  - **Device-independent Software Services**
- **Data Integration**
- **Service Integration**

Supporting Multiple Devices Via Active Mediator



Information Client

Active Object Query

Client-Specific Content

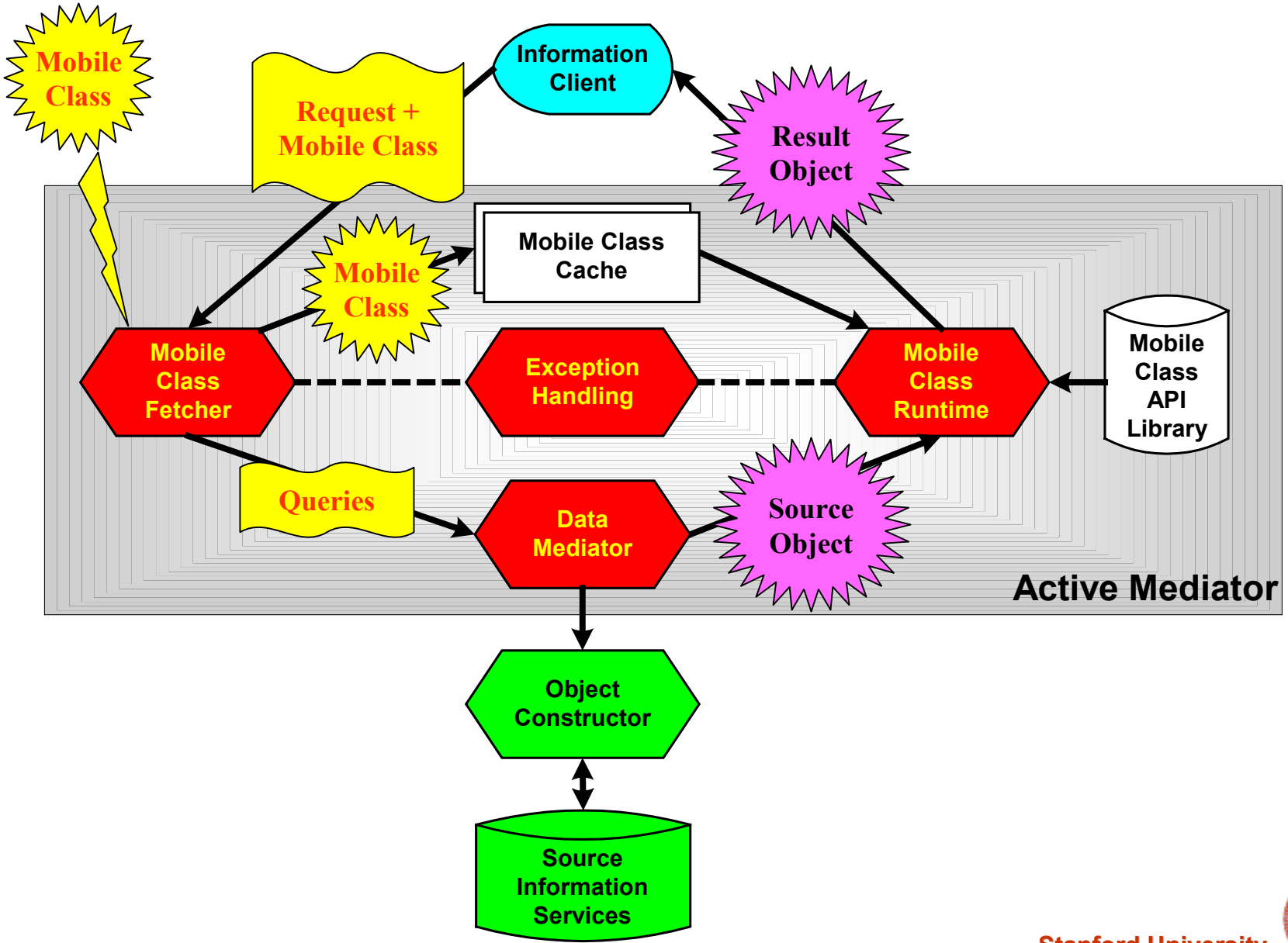
Information Abstraction

Source Query

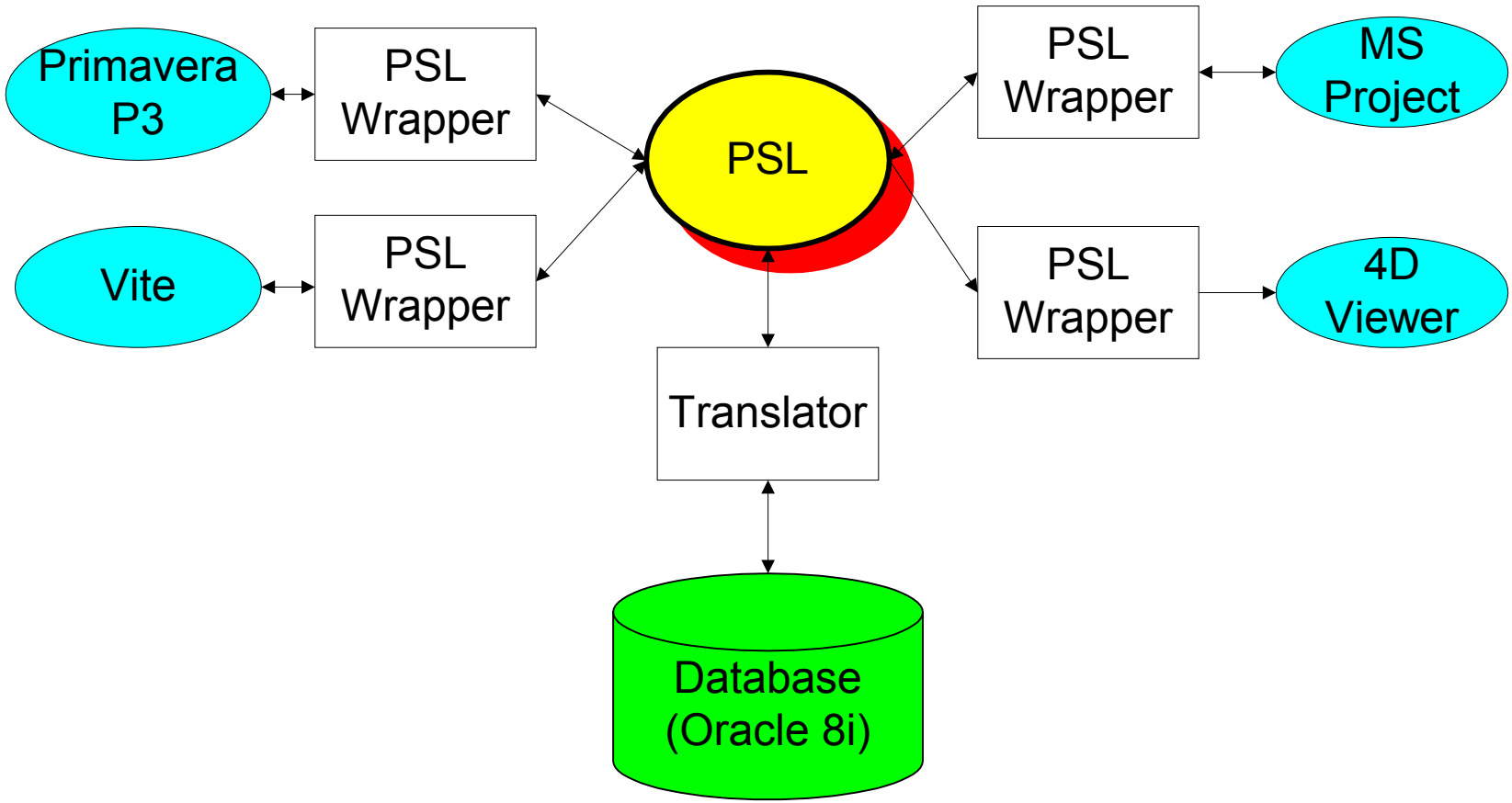
Source Content

Information Content

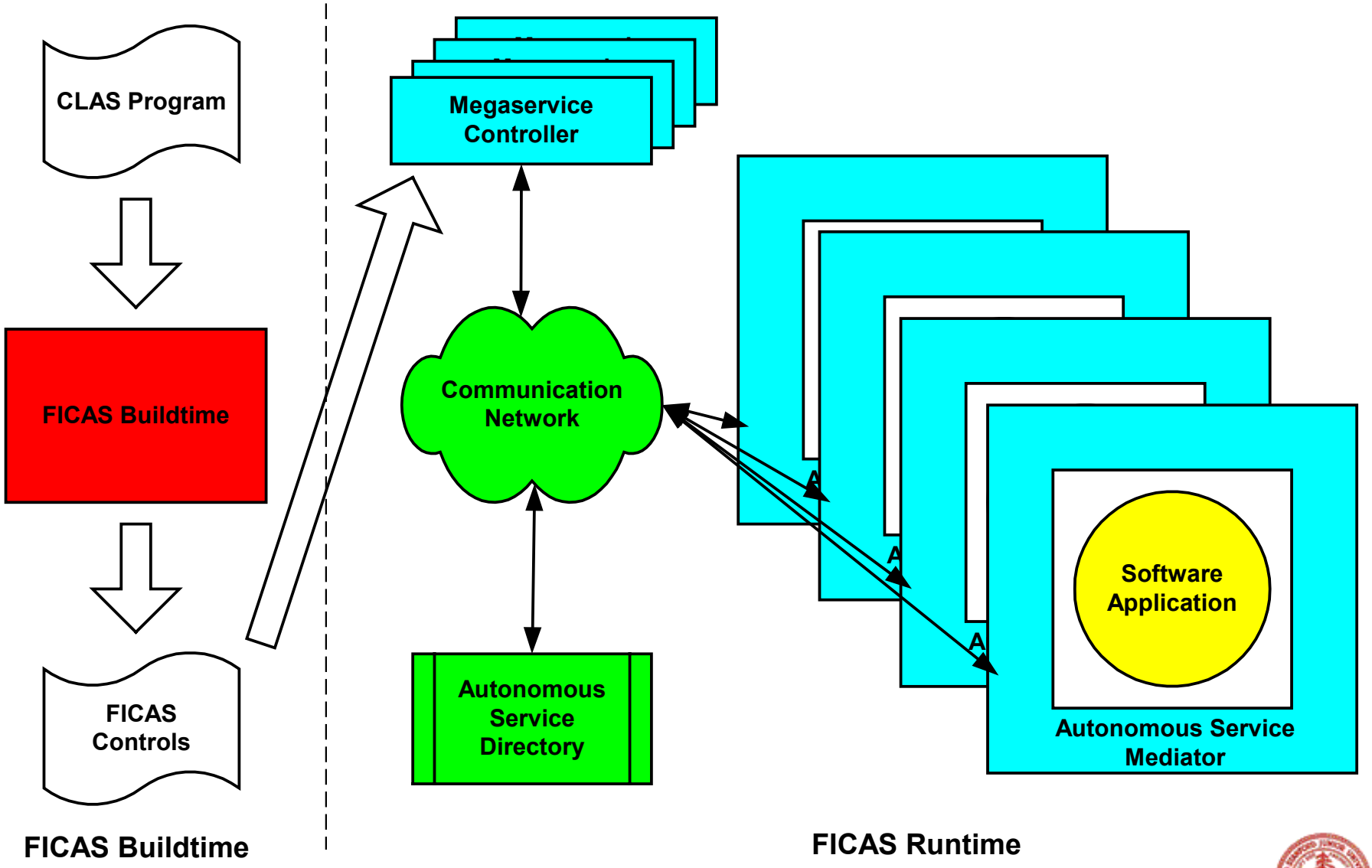
Active Mediator in Action



Using PSL As Standard Exchange Language

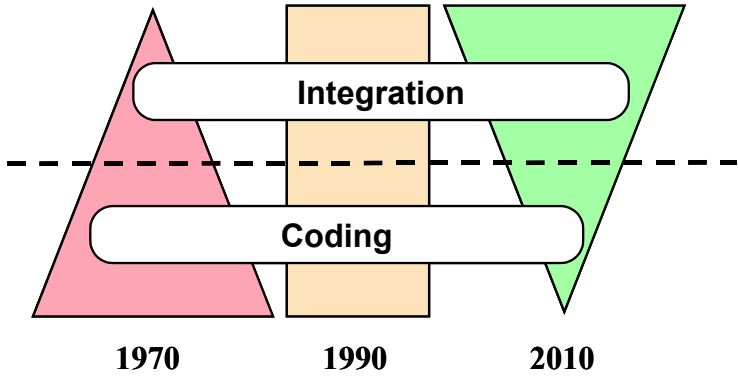


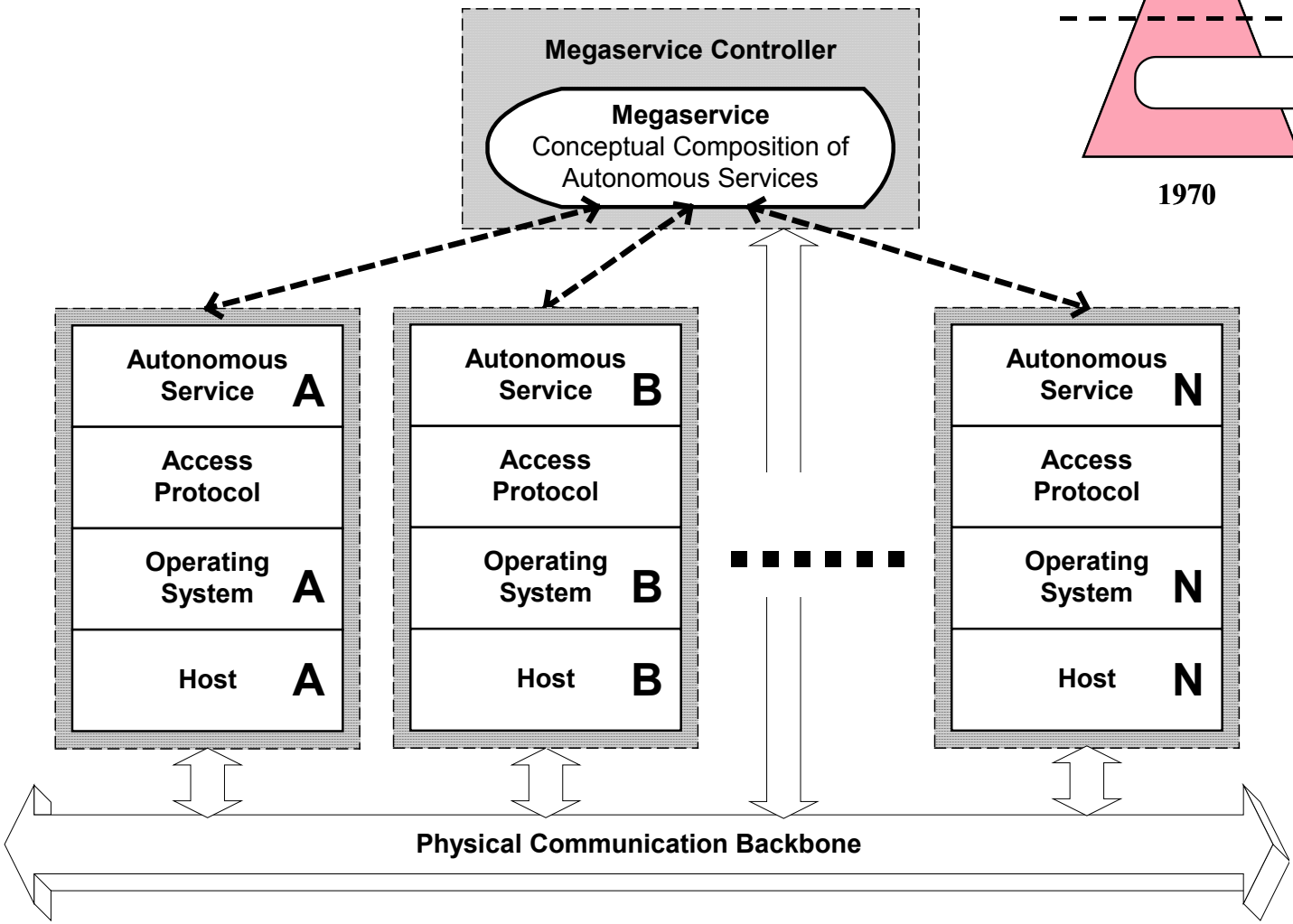
Using FICAS For Service Integration



FICAS
(Flow-based Infrastructure for Composing Autonomous Services)

Service Composition





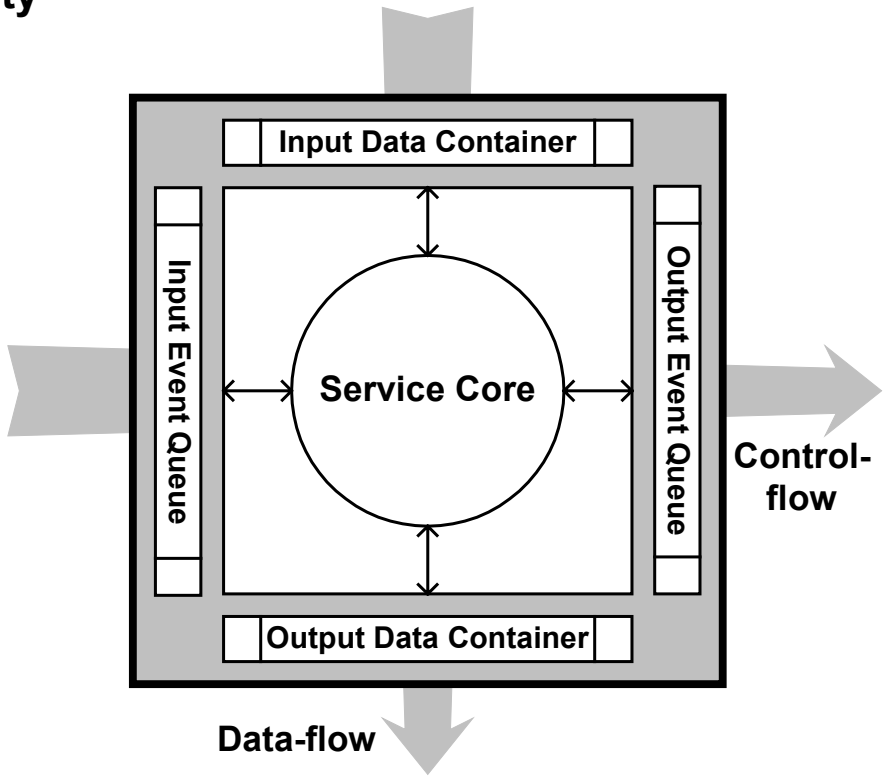
Service Composition Infrastructure

- **A Method to Integrate Software Applications**
  - A access protocol for desired software functionalities
  - ASAP (Autonomous Service Access Protocol)
- **A Method to Specify Functionality**
  - A compositional language
  - CLAS (Compositional Language for Autonomous Services)
- **An Environment to Execute Composed Services**
  - A runtime environment that coordinates control-flows and data-flows
  - FICAS (Flow-based Infrastructure for Composition Autonomous Services)

ASAP
(Autonomous Service Access Protocol)

Autonomous Service Metamodel

- **Service Core**
  - Represents the core service functionality
  - Wraps an existing software application
- **Data Containers**
  - Handle input and output data
  - Form data-flows
  - Enable distributed data-flows
- **Event Queues**
  - Handle inquiries and issue requests
  - Form control-flows
  - Enable asynchronous service invocations



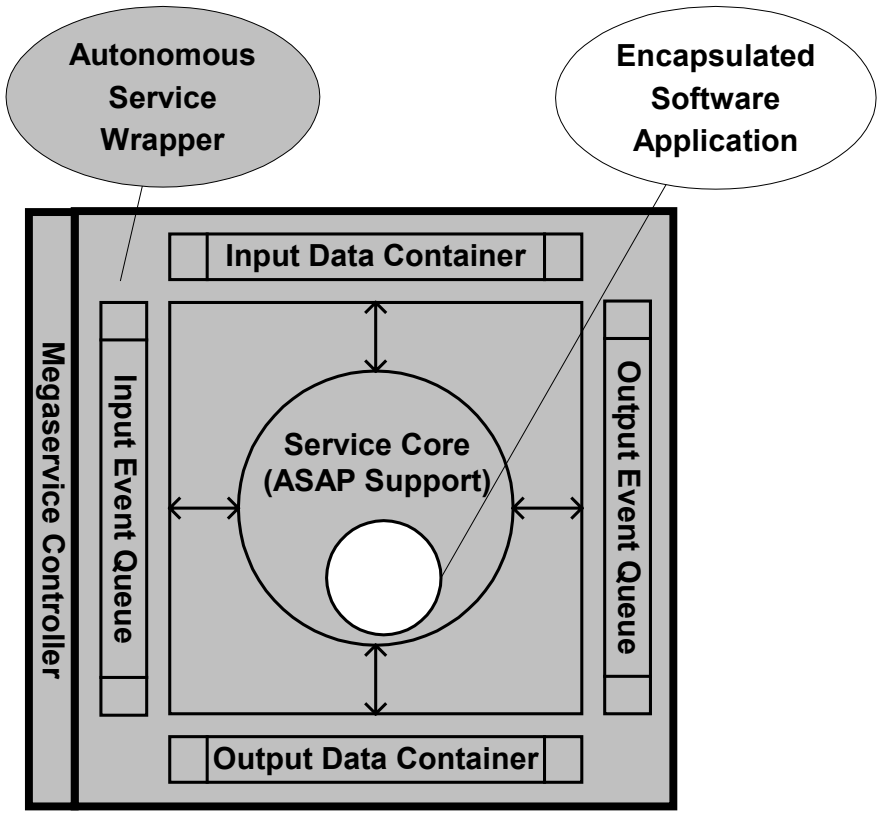
Autonomous Service Access Protocol (ASAP)

- **ASAP**
  - A light-weight, asynchronous and non-blocking event-based protocol
  - Defines how autonomous services respond to events
  - XML is used as transport medium for both control and data

- **ASAP Events**
  - SETUP, TERMINATE: Initialization / termination of autonomous services
  - INVOKE: Invocation of autonomous services
  - MAPDATA: Management of data-flow between autonomous services
  - CONTROLFILE: Execution of megaservice control files

Autonomous Service Wrapper (ASW)

- **Purposes of ASW**
  - Facilitate wrapping of software applications into autonomous services
  - Implement data containers and event queues
  - Implement ASAP protocol




```
public interface ServiceCore
{
  public boolean setup(
    Container inc,
    Container outc,
    FlowId inf);

  public boolean execute(
    Container inc,
    Container outc,
    FlowId inf);

  public boolean terminate(
    Container inc,
    Container outc,
    FlowId inf);
}
```

CLAS
(Compositional Language for Autonomous Services)

CLAS

- **Compositional Language for Autonomous Services**
  - **A high-level declarative language**
  - **Based on CLAM language developed in CHAIMS**
  - **Simple (Intended for domain experts, NOT technical experts)**
  - **Separation between composition and computation**

- **Features**
  - **Decomposition of a CALL statement into 4 primitives**
    - SETUP, INVOKE, EXTRACT, TERMINATE
  - **Control primitives**
    - IF … THEN … ELSE
    - WHILE
  - **Mobile class**
    - For specifying computational logic

Mobile Class for Specifying Computational Logic

- **Mobile Class**
  - Java based
  - Dynamic routines that performs complex computational logic
  - Reusable
- **Example of Mobile Class**
  - Relational operators

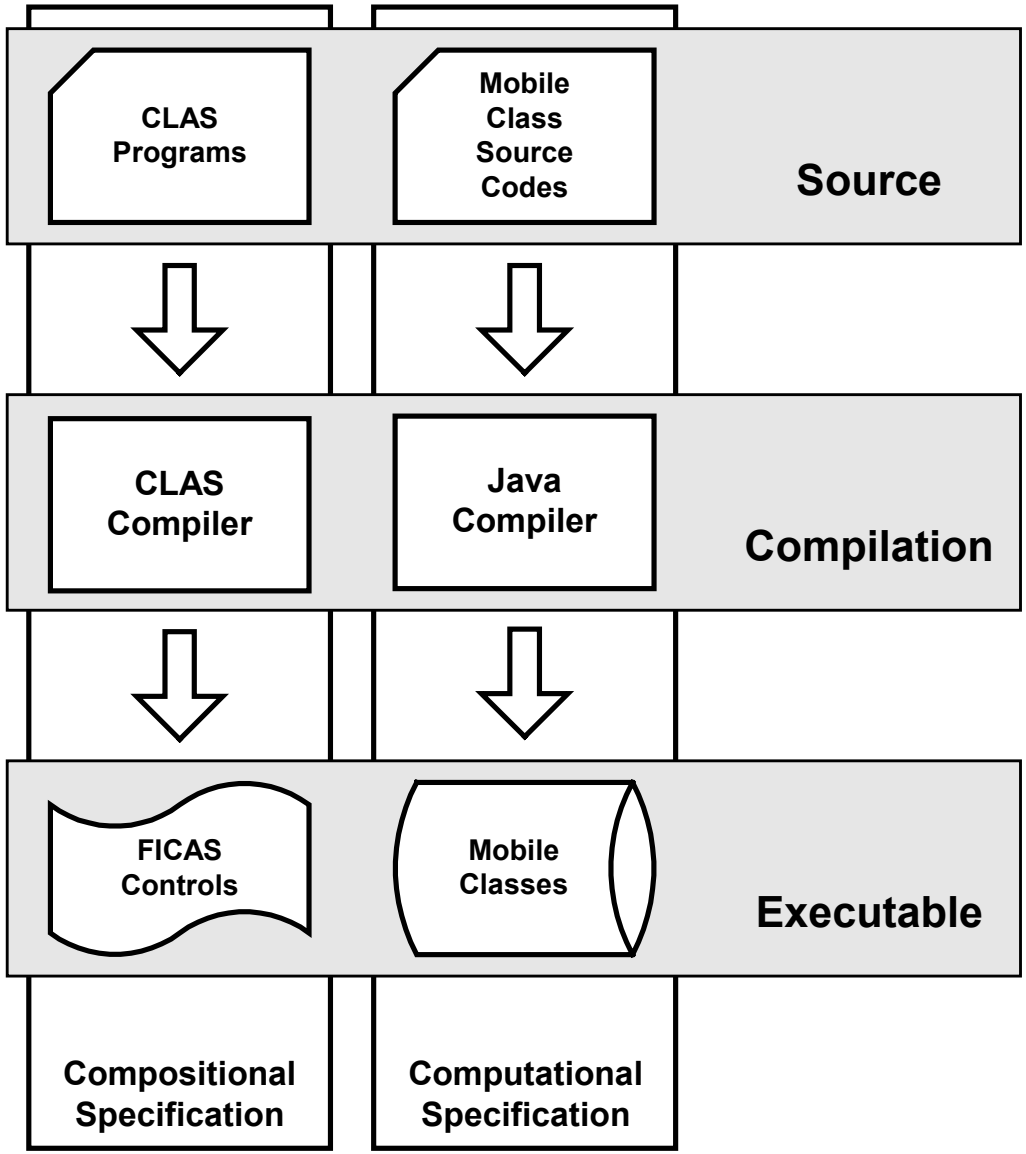
    $\sigma_{cond}(A)$, $\pi_{attr}(A)$, $A \triangleright\triangleleft_{cond} B$
  - Arithmetic operators

    +, -, ×, /
  - Data aggregation and abstraction
  - Type conversions

```
/* Specification of a type conversion mobile class */
public class int2float implements MobileClass
{
   public DataElement execute(Vector params) {
      DataElement arg =
         (DataElement) params.firstElement();
      int val = arg.getIntValue();
      return new DataElement().setValue(
         new Double(val).doubleValue());
   }
}
```

```
/* Using m-class in a CLAS program */
floatnum = MCLASS("int2float", num)
```


FICAS Buildtime

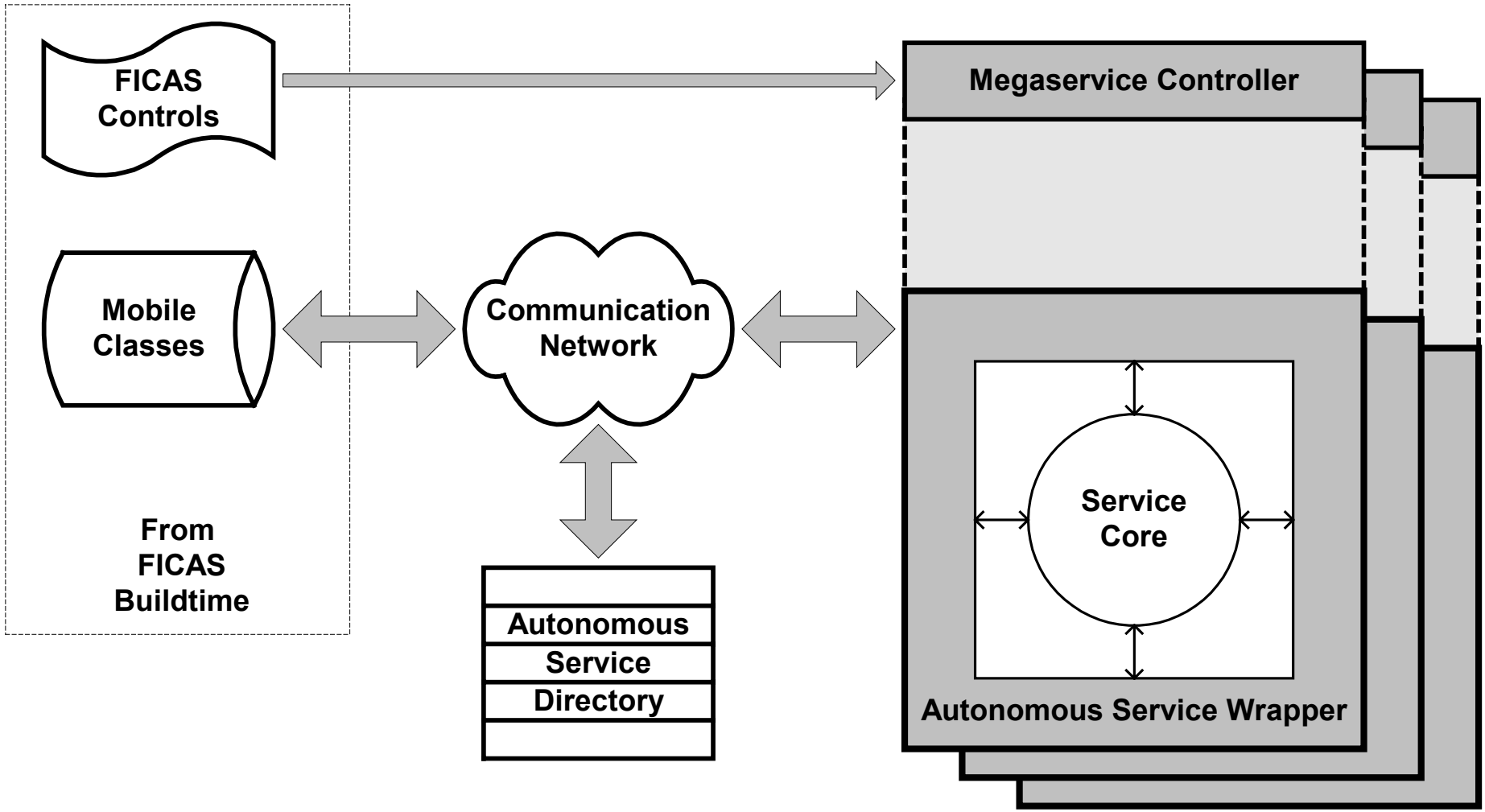


Sample CLAS Program 1

```
SchedulingDemo "http://ficas.stanford.edu/Megaprogram"
{
        /* Setup Services */
        psl_svc = SETUP("SIPsl")
        p3_svc = SETUP("SIP3")
        notification_svc = SETUP("SINotification")

        /* Invoke and extract information from PSL Service */
        psl = psl_svc.INVOKE("to-psl", "CEIL")
        ceil = psl.EXTRACT()

        /* Invoke Rescheduling Service */
        p3 = p3_svc.INVOKE("reschedule", ceil)
        ceil2 = p3.EXTRACT()

        /* Store information using PSL Service */
        oracle = psl_svc.INVOKE("to-oracle", ceil2)
        status = oracle.EXTRACT()

        /* Invoke Notification Service */
        notif = notification_svc.INVOKE("171.64.55.32", 8250, status)

        /* Terminate Services */
        psl_svc.TERMINATE()
        p3_svc.TERMINATE()
        notification_svc.TERMINATE()
}
```


FICAS Runtime

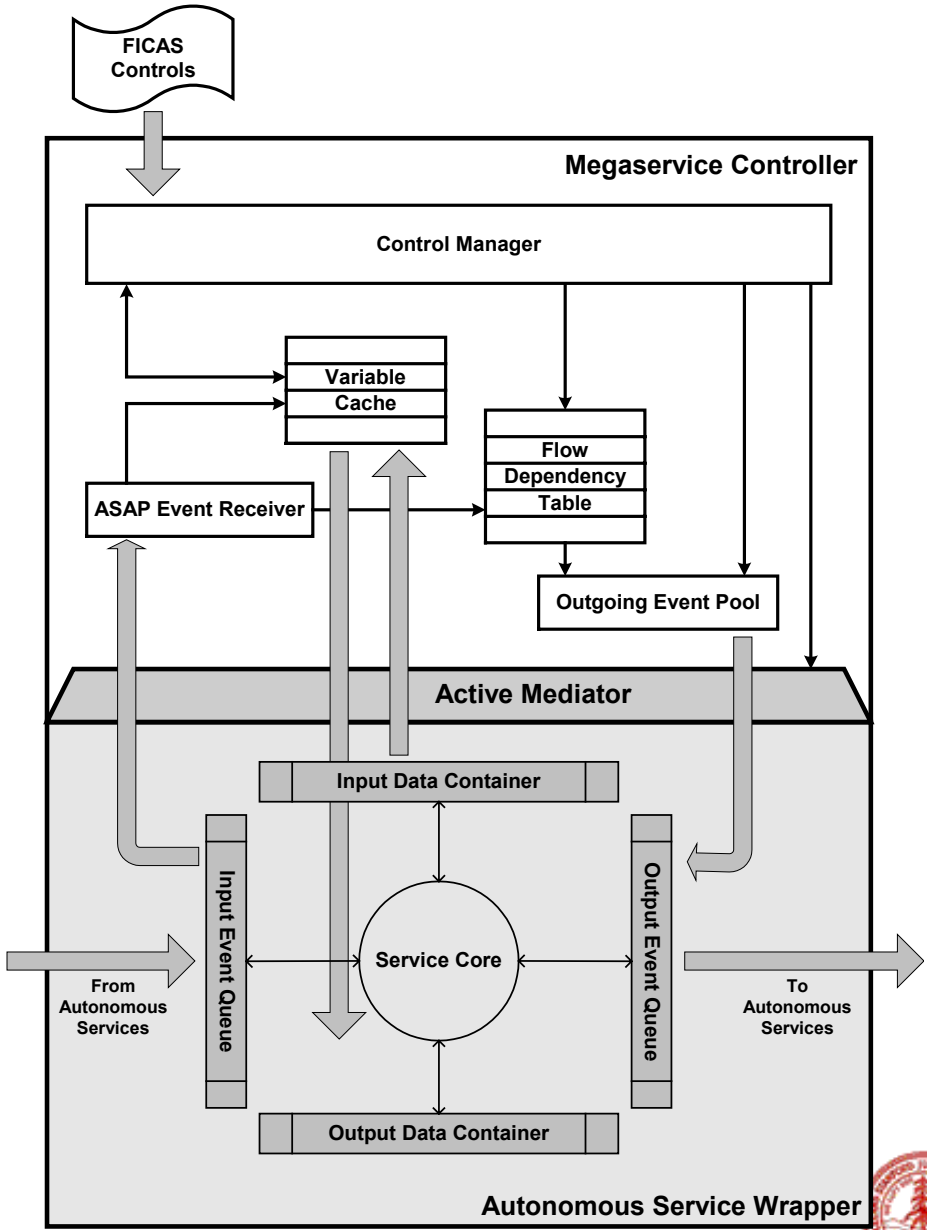
FICAS Runtime Architecture



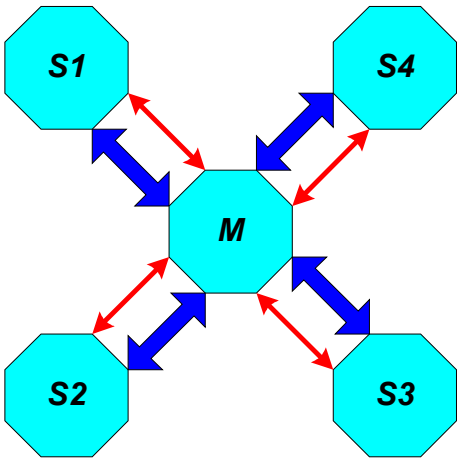
Megaservice Controller

FICAS Control Sequence

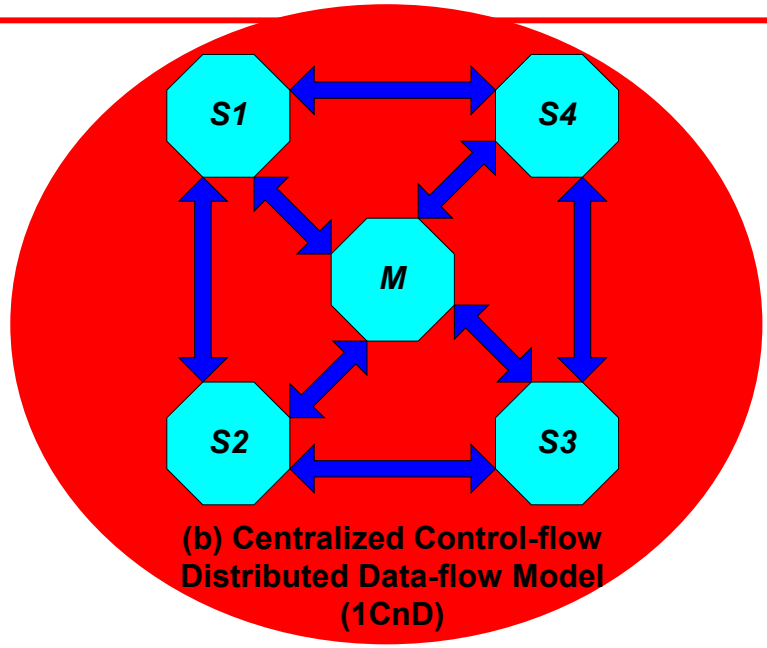
```
……

<INVOKE>
  <INVOCATIONHANDLE>Invocation1</INVOCATIONHANDLE>
  <SERVICEHANDLE>Service1</SERVICEHANDLE>
</INVOKE>
<INVOKE>
  <INVOCATIONHANDLE>Invocation2</INVOCATIONHANDLE>
  <SERVICEHANDLE>Service2</SERVICEHANDLE>
</INVOKE>
<EXTRACT>
  <VARIABLE>A</VARIABLE>
  <INVOCATIONHANDLE>Invocation1</INVOCATIONHANDLE>
</EXTRACT>
<EXTRACT>
  <VARIABLE>B</VARIABLE>
  <INVOCATIONHANDLE>Invocation2</INVOCATIONHANDLE>
</EXTRACT>
<INVOKE>
  <INVOCATIONHANDLE>Invocation3</INVOCATIONHANDLE>
  <SERVICEHANDLE>Service3</SERVICEHANDLE>
  <VALUELIST>
    <VARIABLE>A</VARIABLE>
    <VARIABLE>B</VARIABLE>
  </VALUELIST>
</INVOKE>

……
```



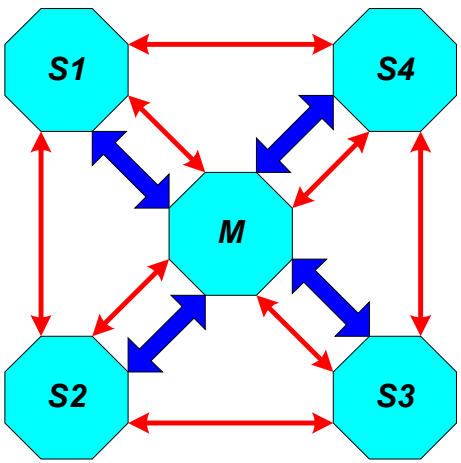
Service Integration Models



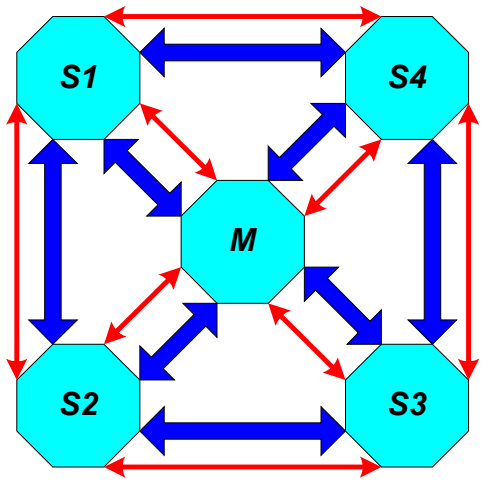
(a) Centralized Control-flow
Centralized Data-flow Model
(1C1D)



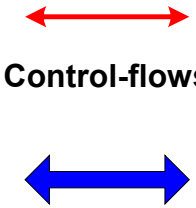
(b) Centralized Control-flow
Distributed Data-flow Model
(1CnD)



(c) Distributed Control-flow
Centralized Data-flow Model
(nC1D)



(d) Distributed Control-flow
Distributed Data-flow Model
(nCnD)

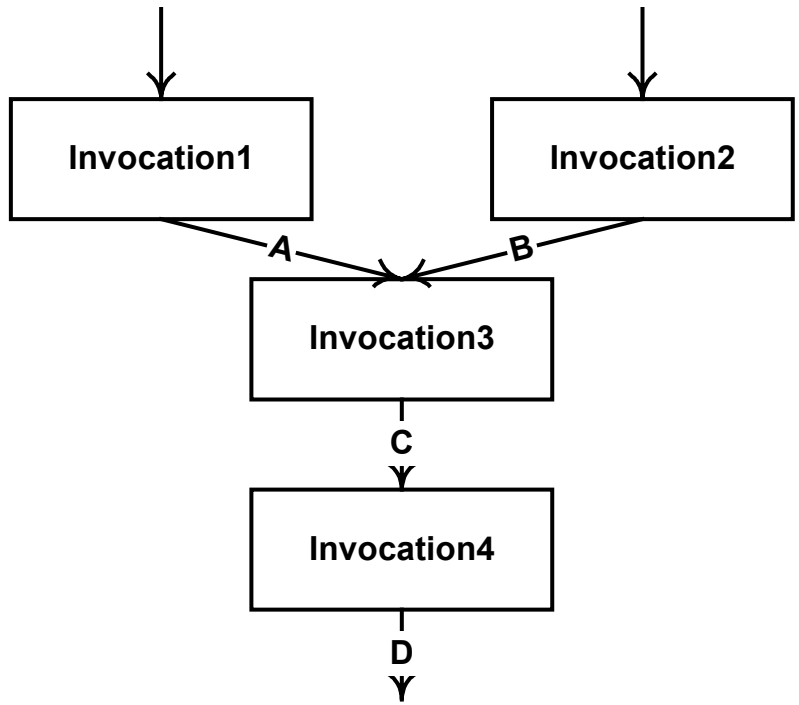


M
Megaservice

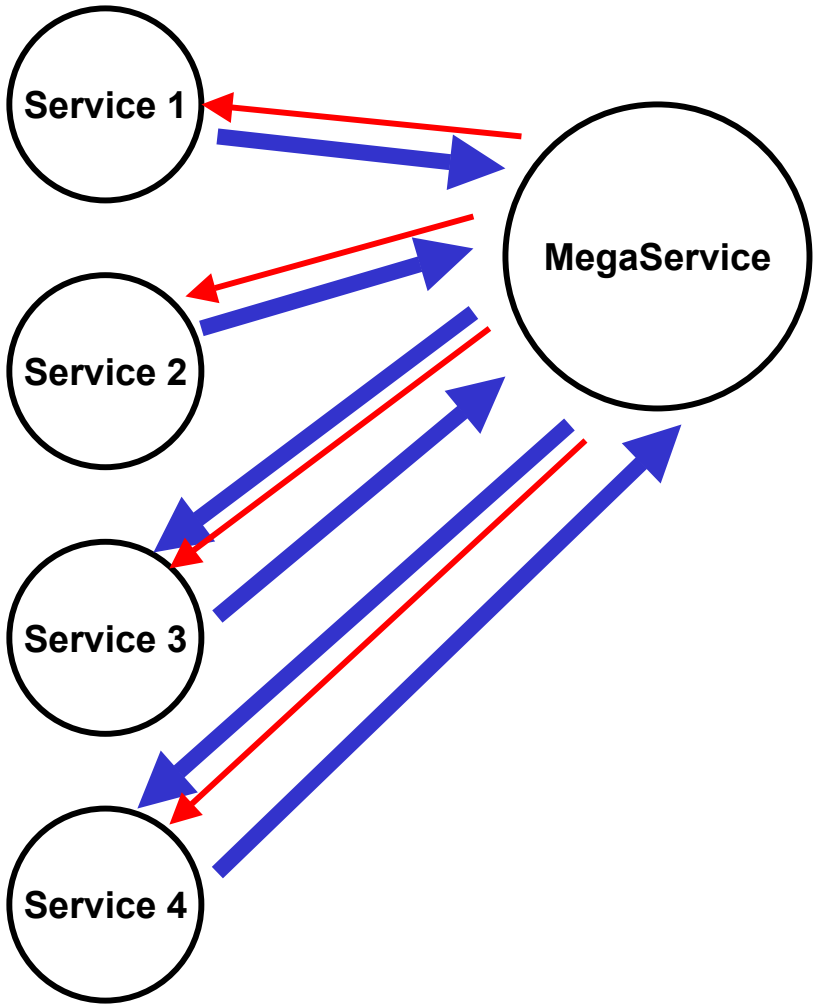
S
Autonomous Services

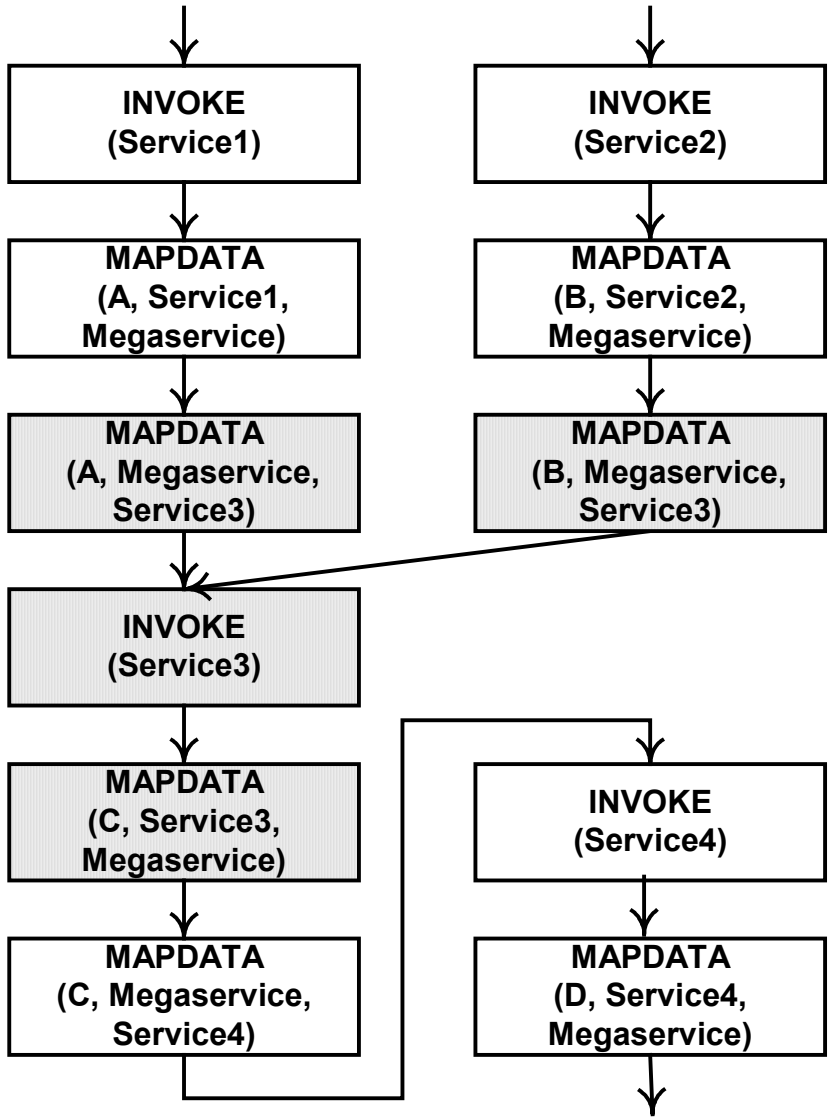
Data Dependencies within Megaservice

```
/* Megaservice specified in CLAS */
Invocation1 = Service1.INVOKE();
Invocation2 = Service2.INVOKE();
A = Invocation1.EXTRACT();
B = Invocation2.EXTRACT();

Invocation3 = Service3.INVOKE(A, B);
C = Invocation3.EXTRACT();

Invocation4 = Service4.INVOKE(C)
D = Invocation4.EXTRACT();
```

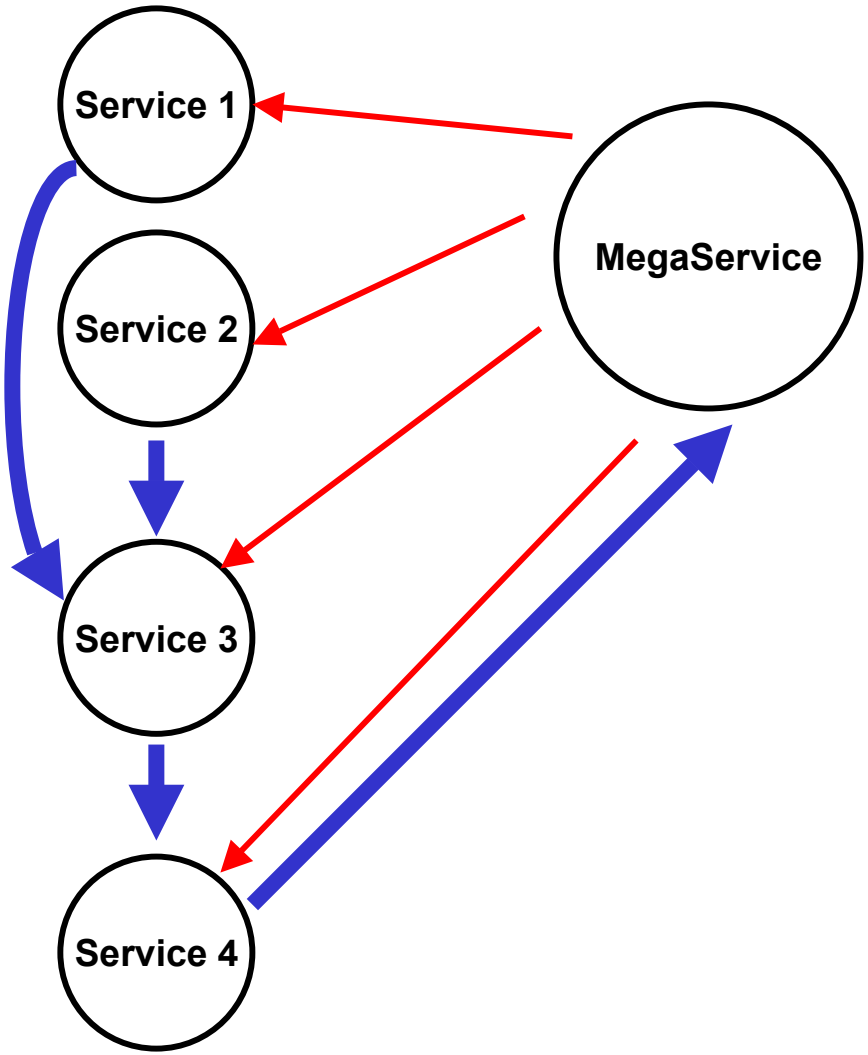


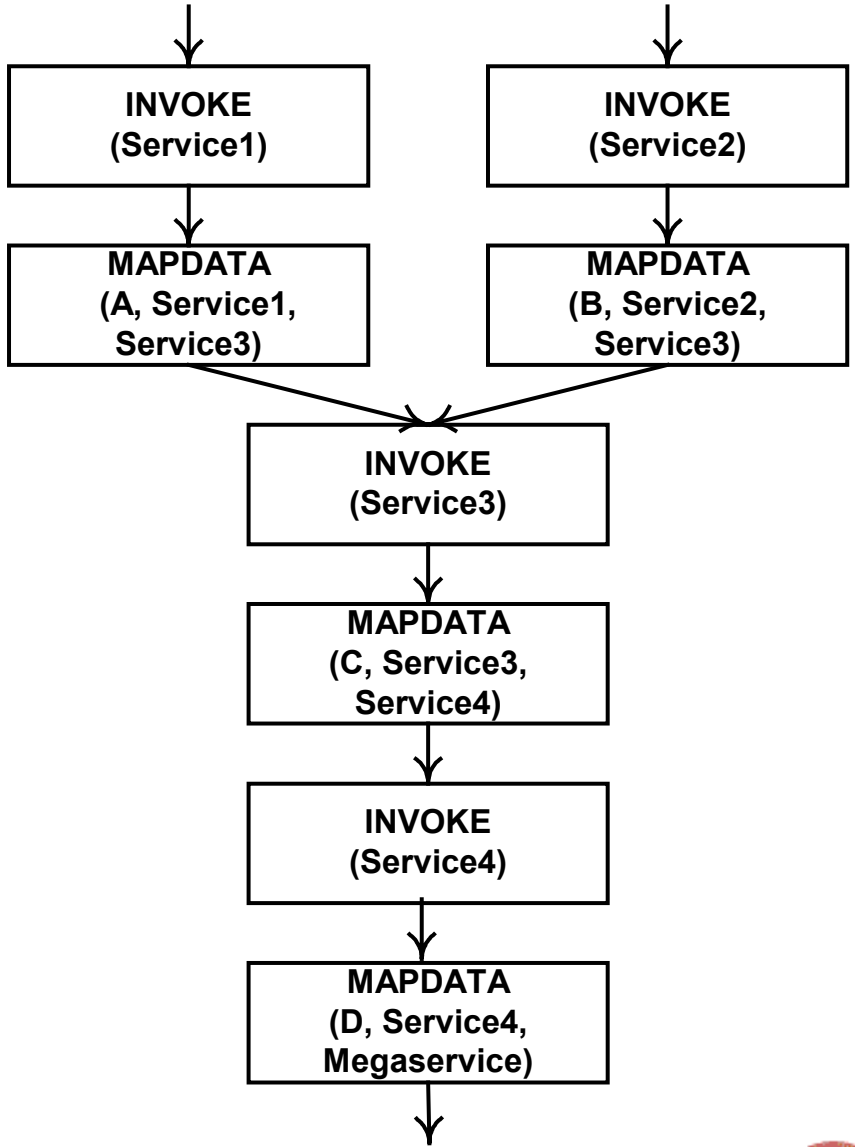
Event Dependency Graph – 1C1D





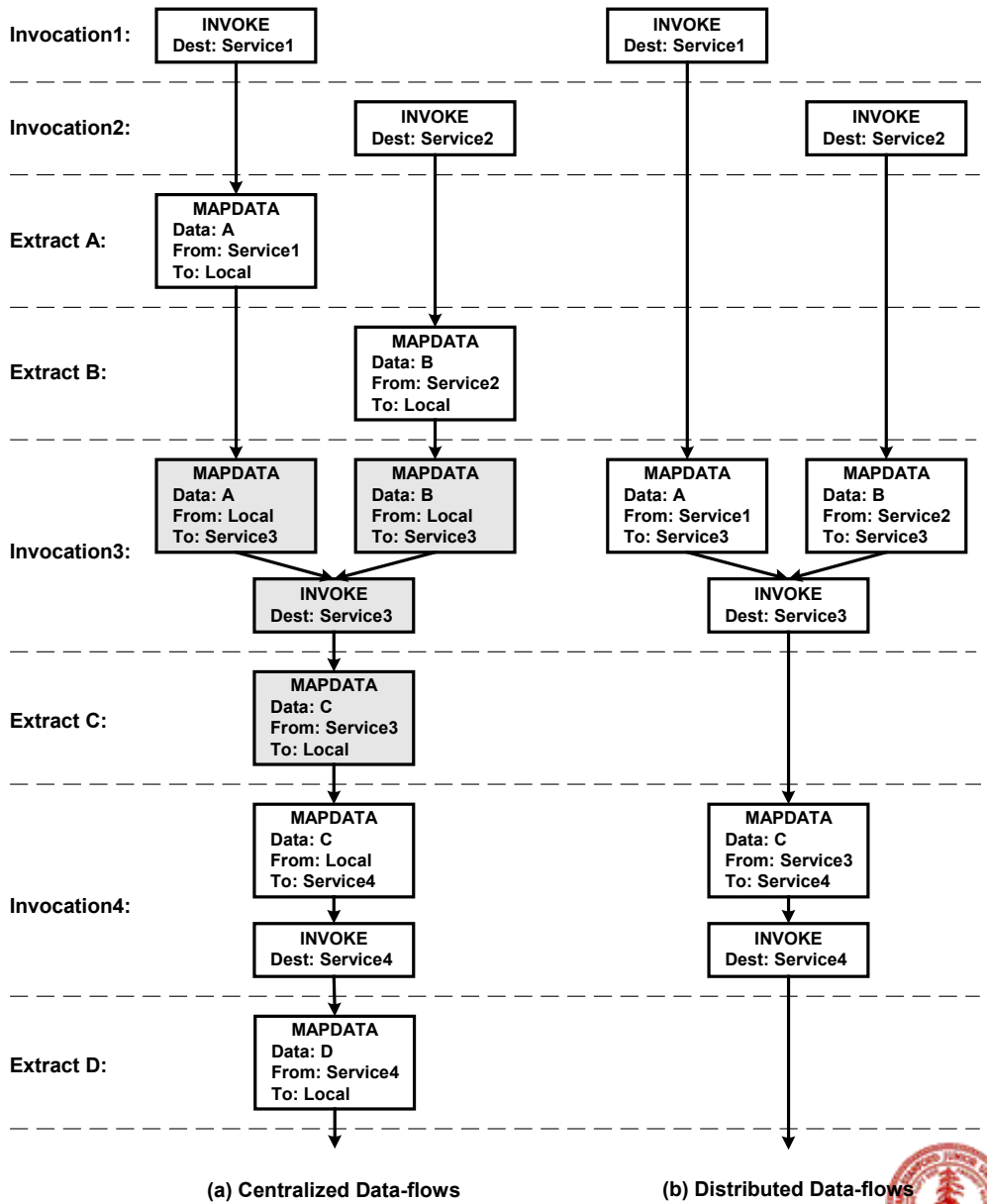
Event Dependency Graph – 1CnD



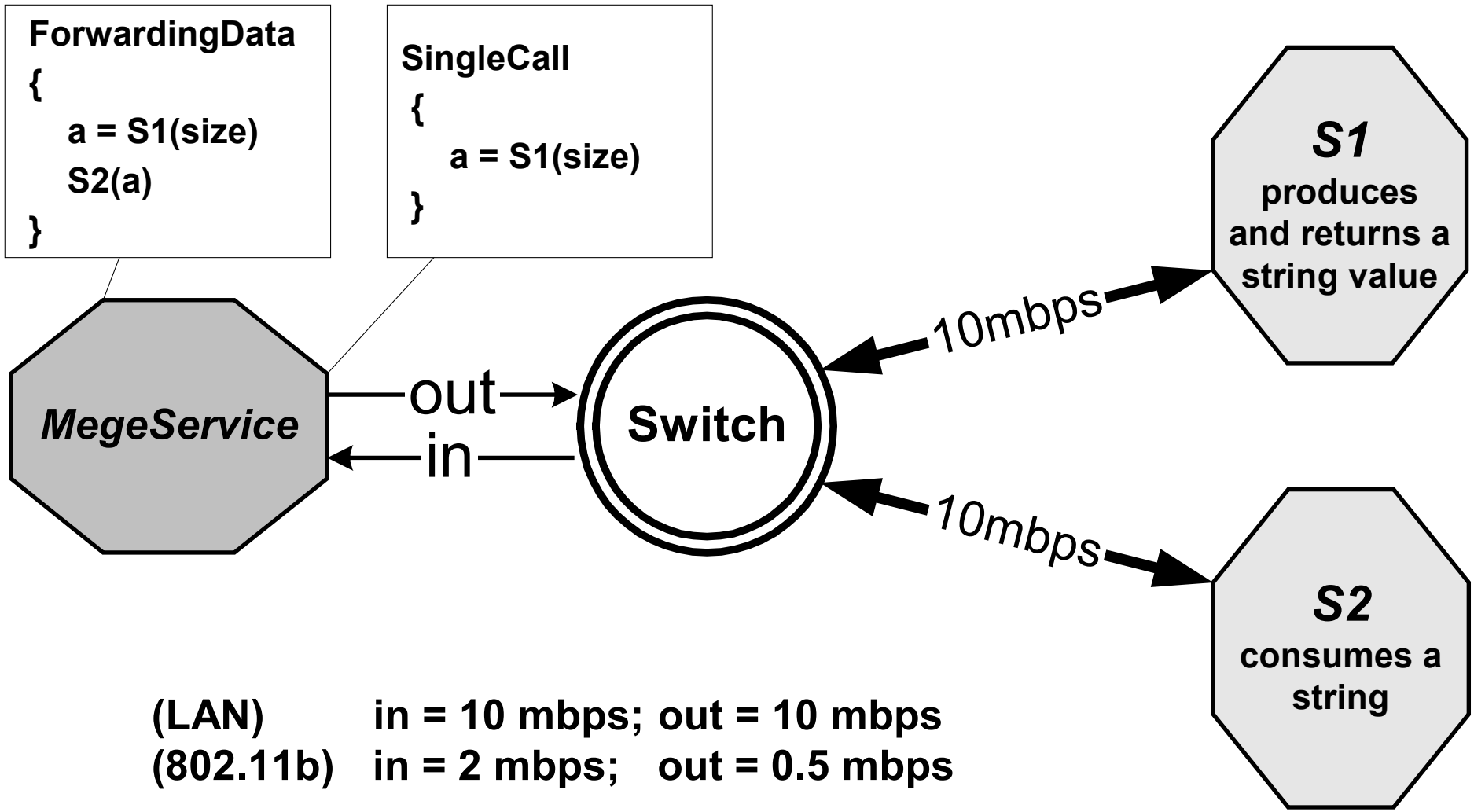


1C1D v.s. 1CnD

```
/* Megaservice specified in CLAS */
Invocation1 = Service1.INVOKE();
Invocation2 = Service2.INVOKE();
A = Invocation1.EXTRACT();
B = Invocation2.EXTRACT();

Invocation3 = Service3.INVOKE(A, B);
C = Invocation3.EXTRACT();

Invocation4 = Service4.INVOKE(C)
D = Invocation4.EXTRACT();
```

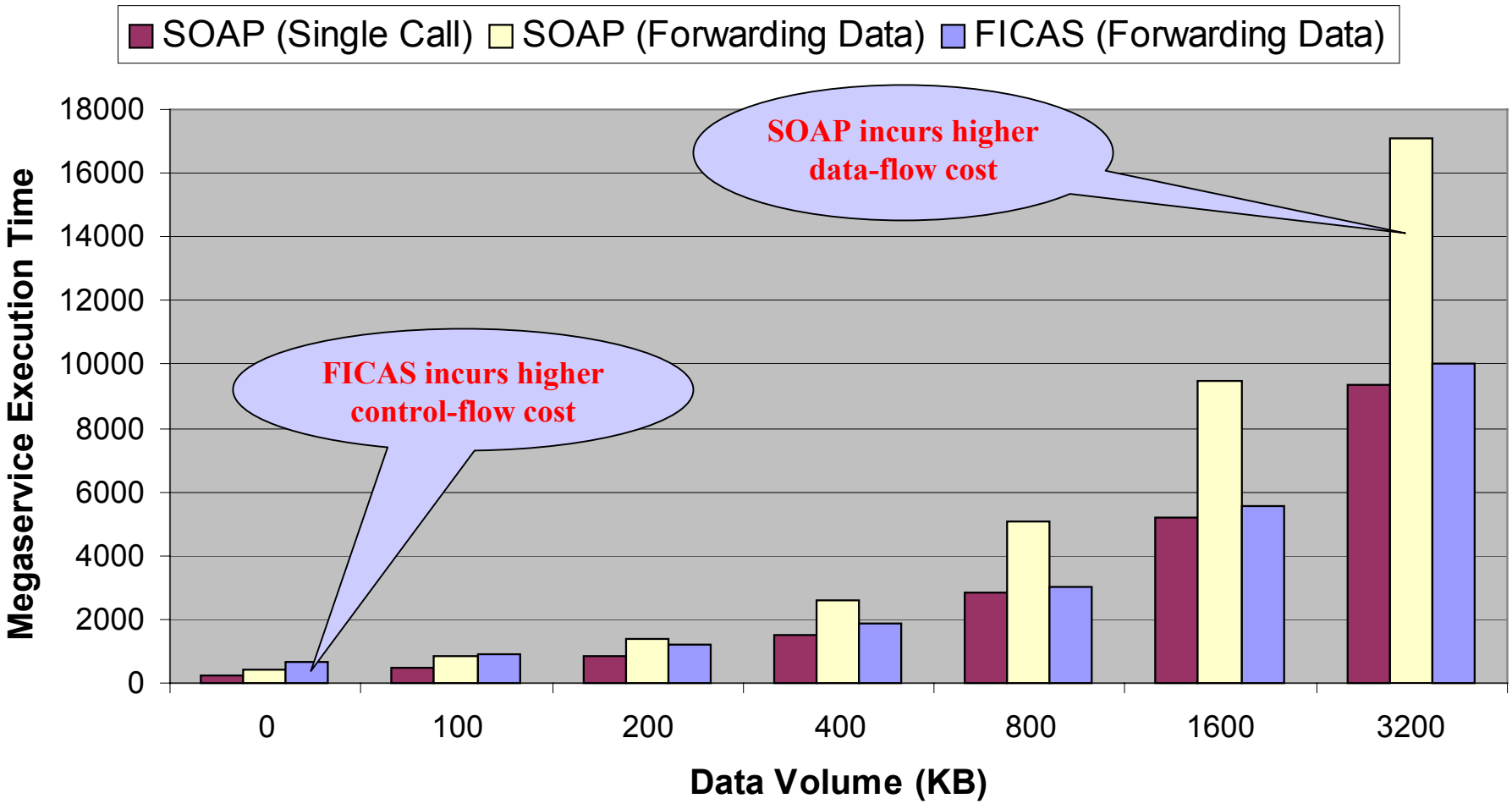


Performance Evaluation – Apache SOAP v.s. FICAS

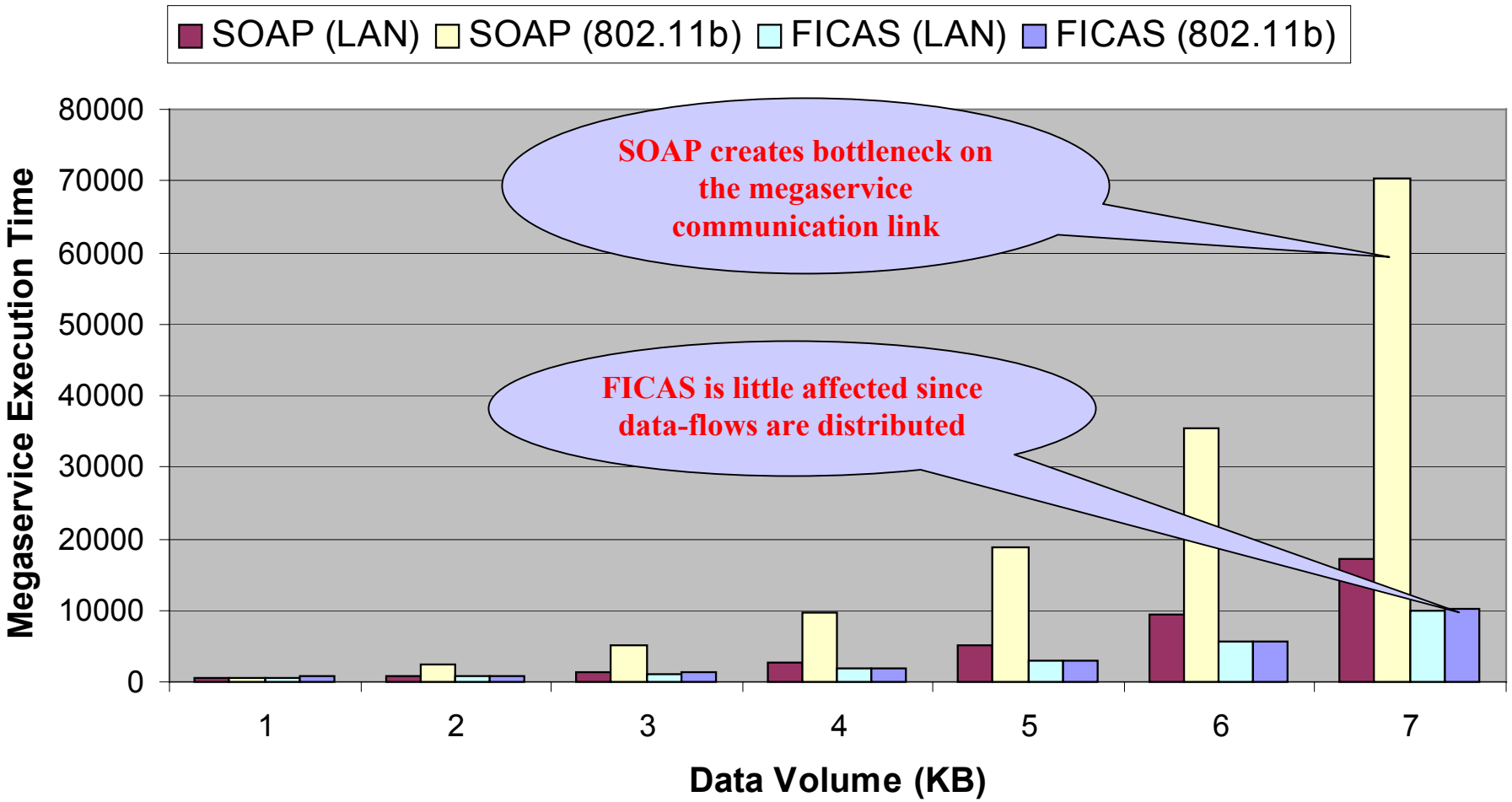


(LAN) in = 10 mbps; out = 10 mbps
(802.11b) in = 2 mbps; out = 0.5 mbps

Megaservice Performance on LAN Setting



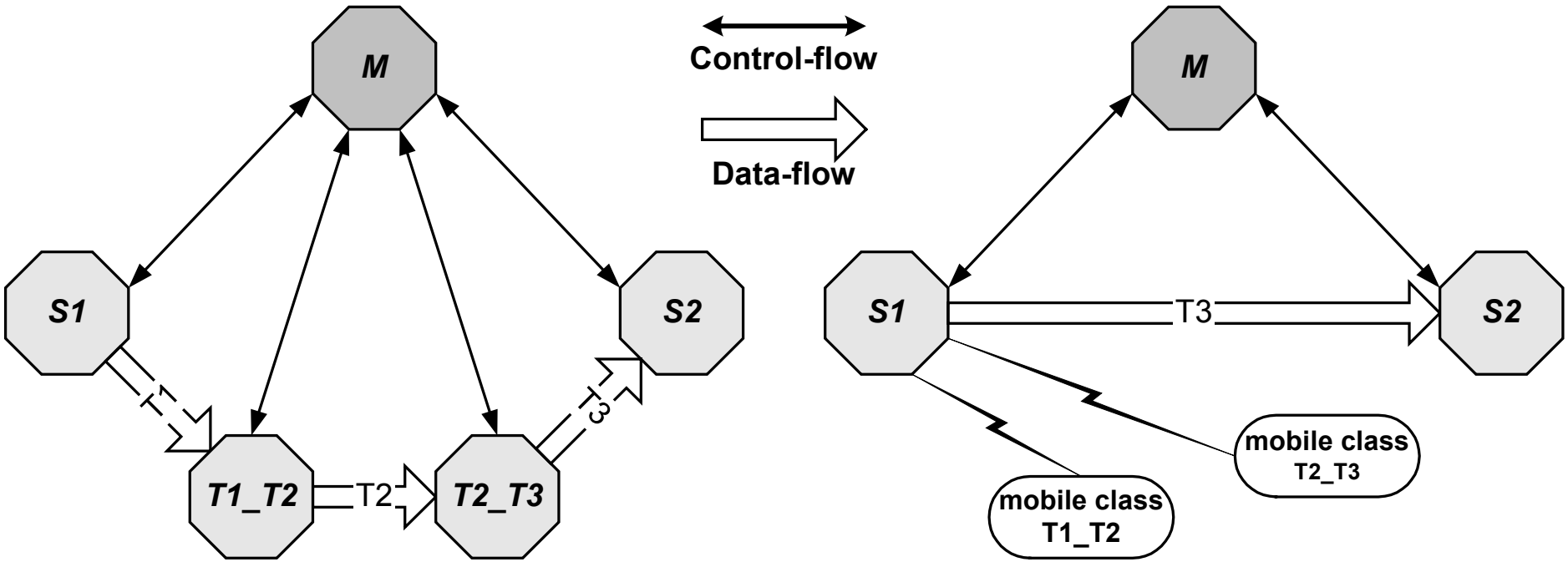
Megaservice Performance on 802.11b Setting



Using Active Mediation for Performance Optimization

Example:

Type Conversion Using Broker Services versus Mobile Classes

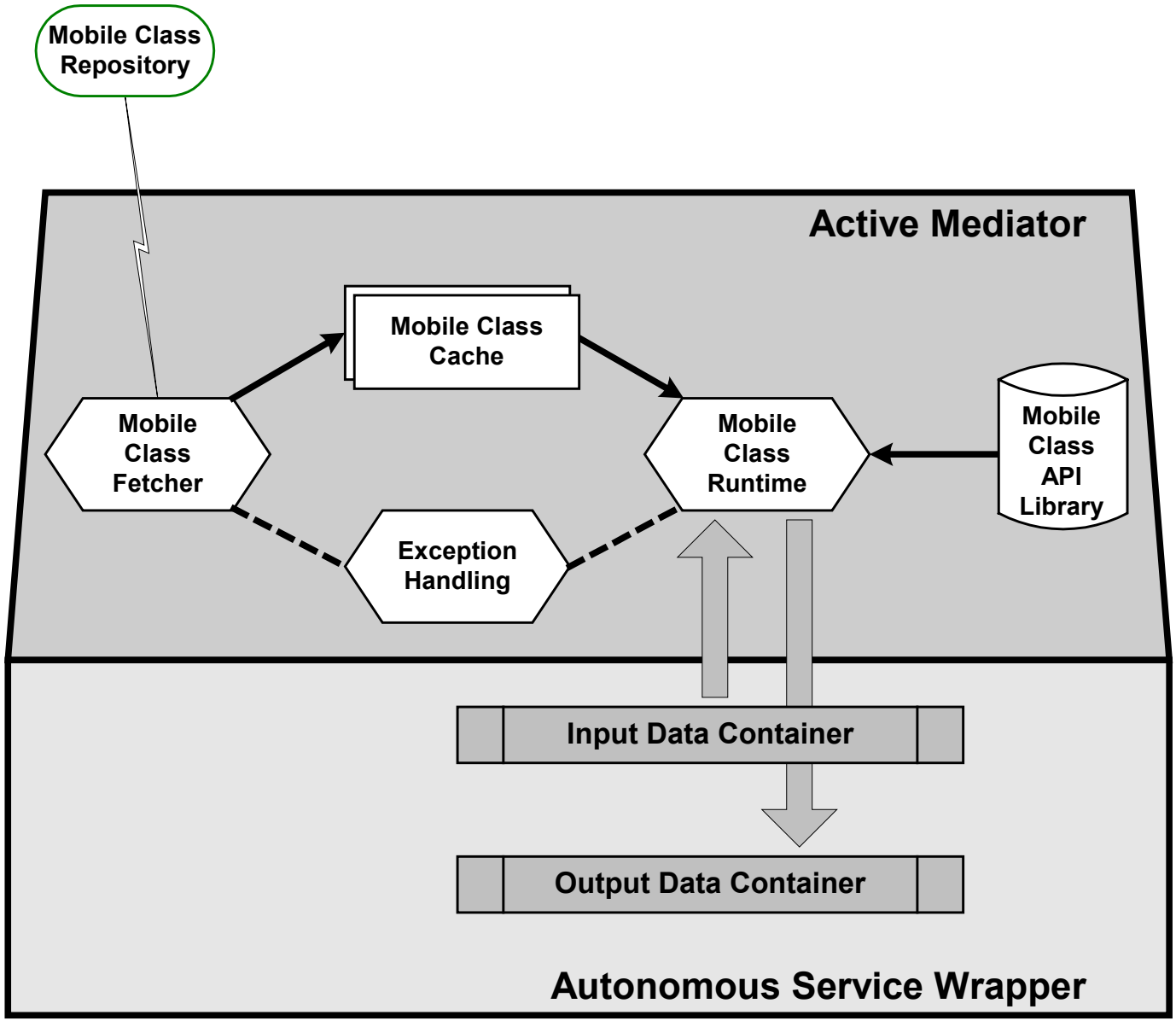


(a) Type Brokers

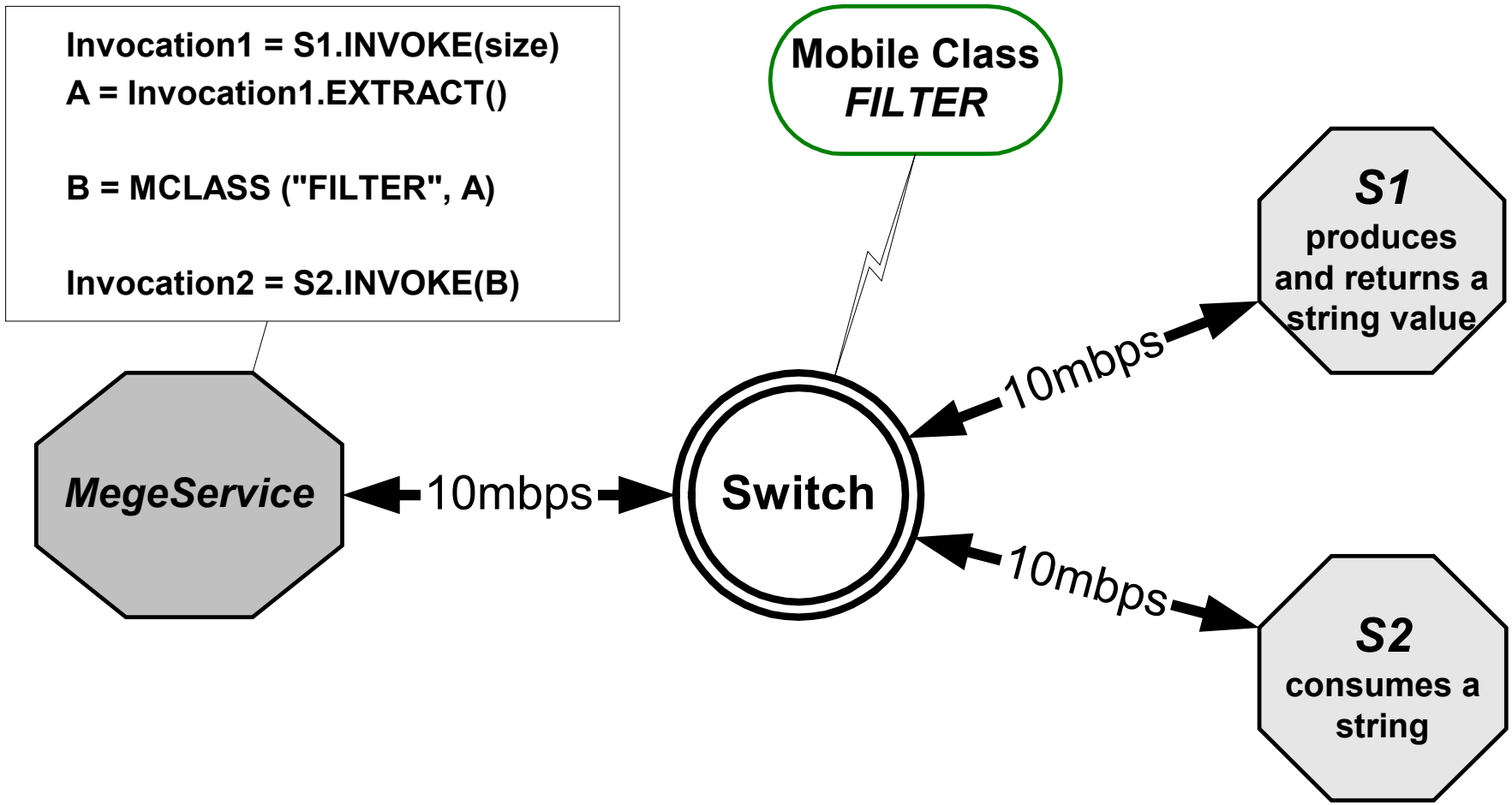
(b) Type Mediation Mobile Classes

J. Ockerbloom, "Mediating Among Diverse Data Formats", Carnegie Mellon University, PhD. Thesis, 1998.

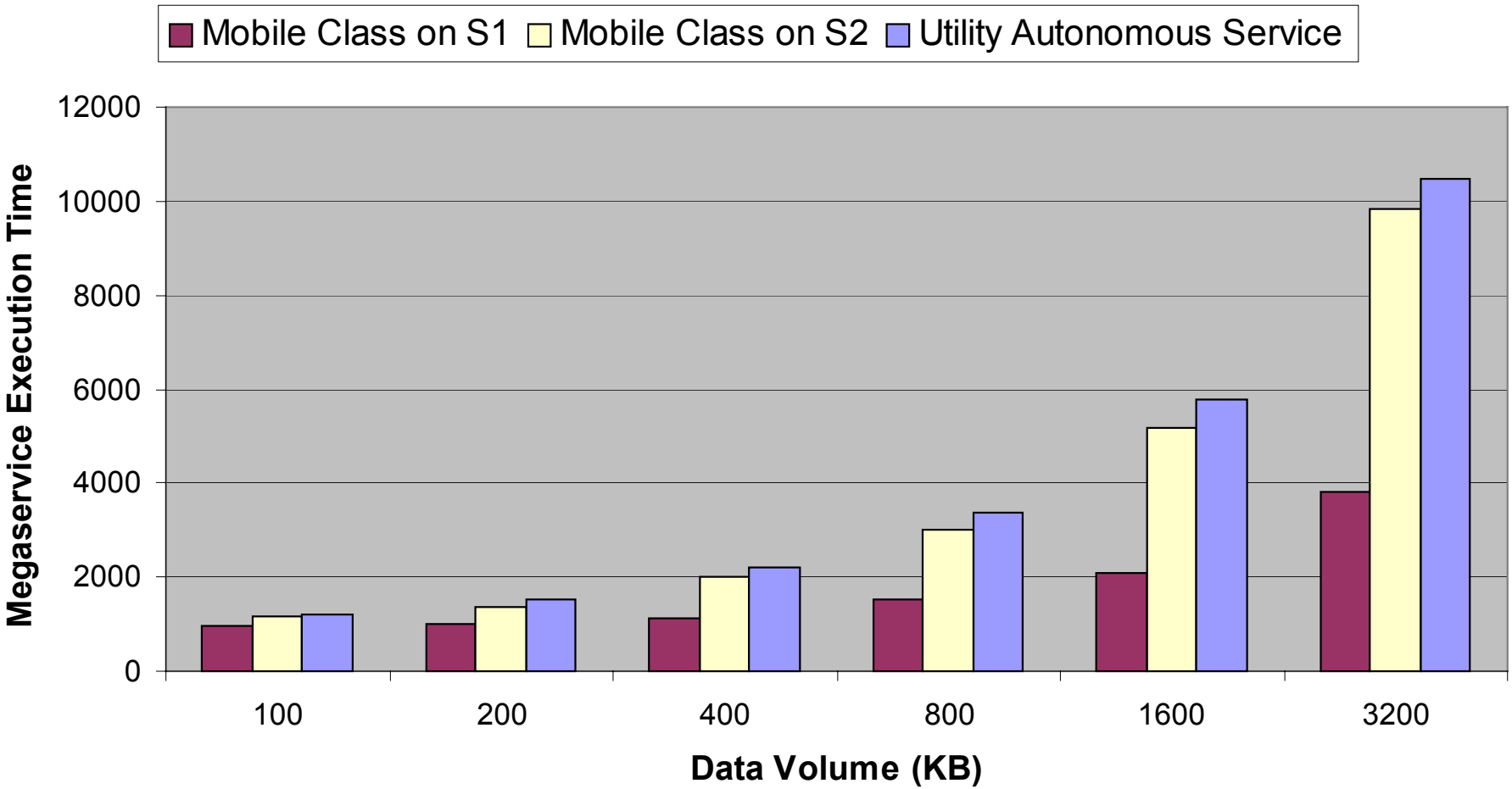
Executing Mobile Class on Active Mediator



A Megaservice with a Mobile Class



Performance Comparison for Mobile Class Placements



Distributed Component Models

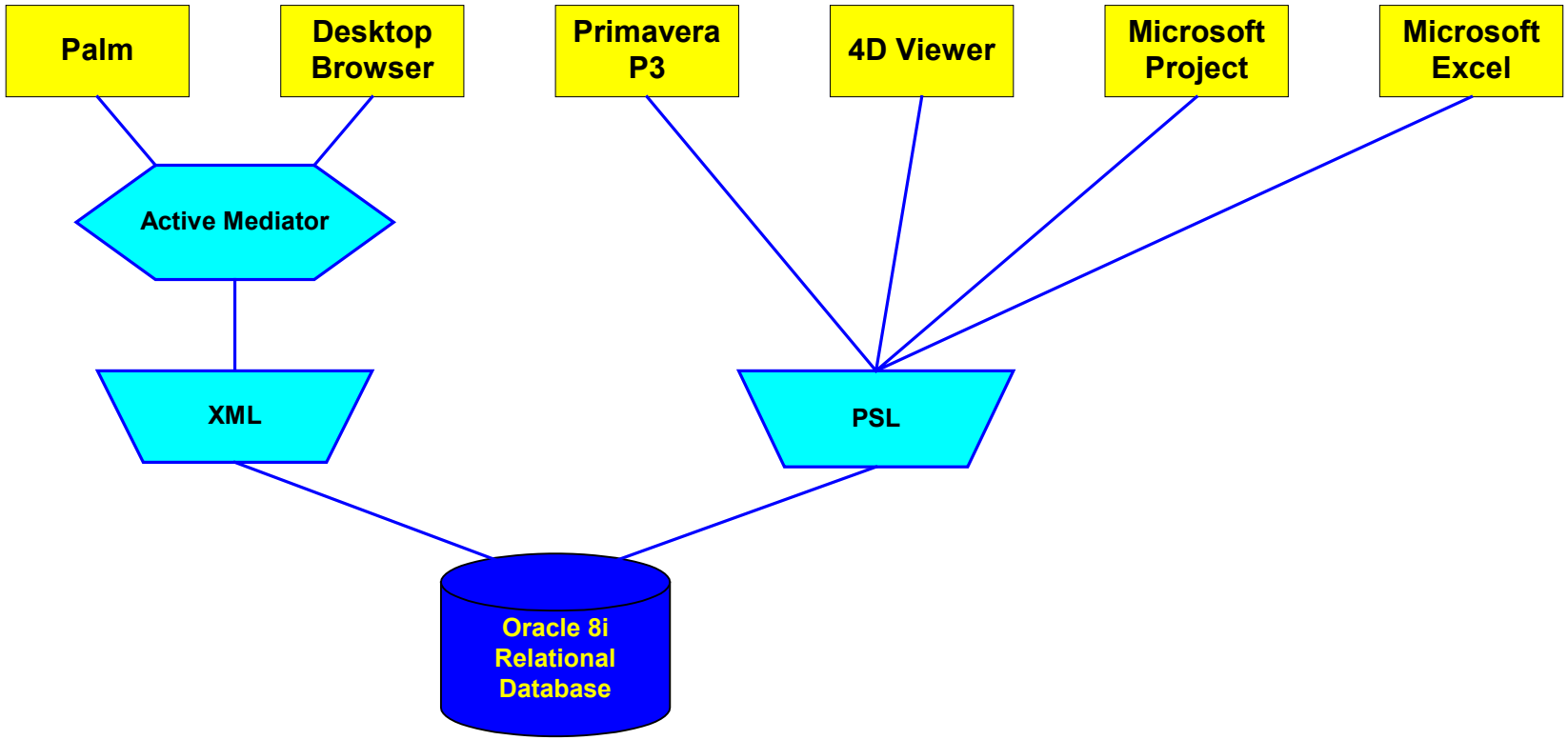
	CORBA	SOAP (Web Service)	FICAS
Data Representation	CDR (Common Data Representation)	XML	XML
Language Paradigm	Method Call	Procedure Call	Procedure Call
Invocation Model	Client-Server	Client-Server	Client-Server Active Mediation
Dataflow Model	Centralized	Centralized	Distributed
Synchronicity	Sync / Asynchronous	Synchronous	Sync / Asynchronous
Transport Protocol	IIOP	HTTP, SMTP	TCP
Remote Reference	Proxy Reference	URL	URL
Service Description	CORBA IDL (Interface Description Language)	WSDL (Web Service Description Language)	N/A
Locating Services	CORBA Naming Service	UDDI (Universal Description, Discovery and Integration)	Autonomous Service Directory

FICAS Summary

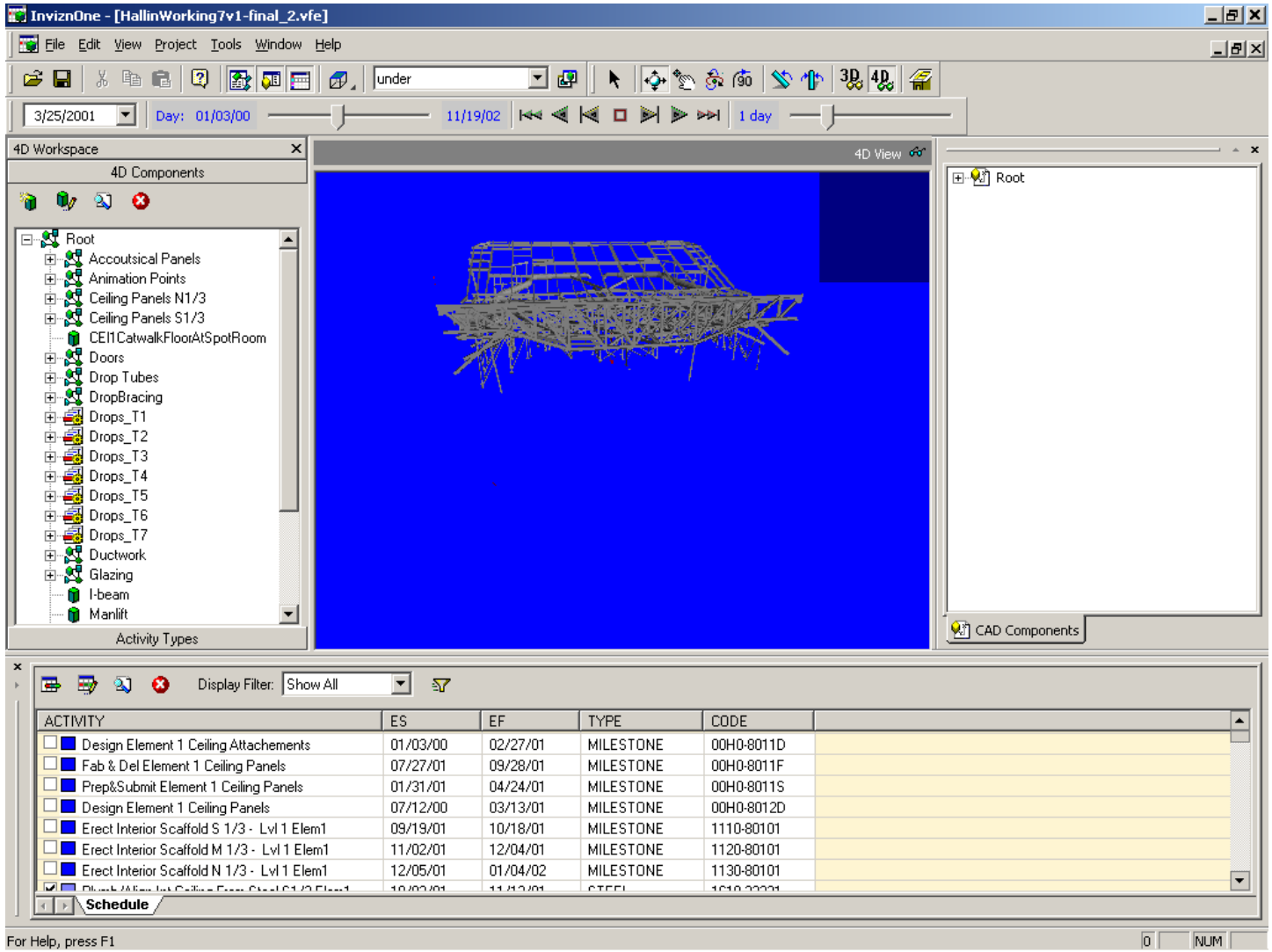
- **Objective**
  - Investigate revolutionary approach to large-scale software composition
- **Approach**
  - Develop and validate a distributed data-flow based service composition framework
- **Contributions**
  - Protocol (*ASAP*) support for constructing autonomous services
  - A high-level language (*CLAS*) that separates composition from computation
  - Performance optimization with data-flow distribution
  - Active mediation to extend the capability of the compositional language and to facilitate data-flow optimization

Demonstration

Putting It All Together – Demonstration

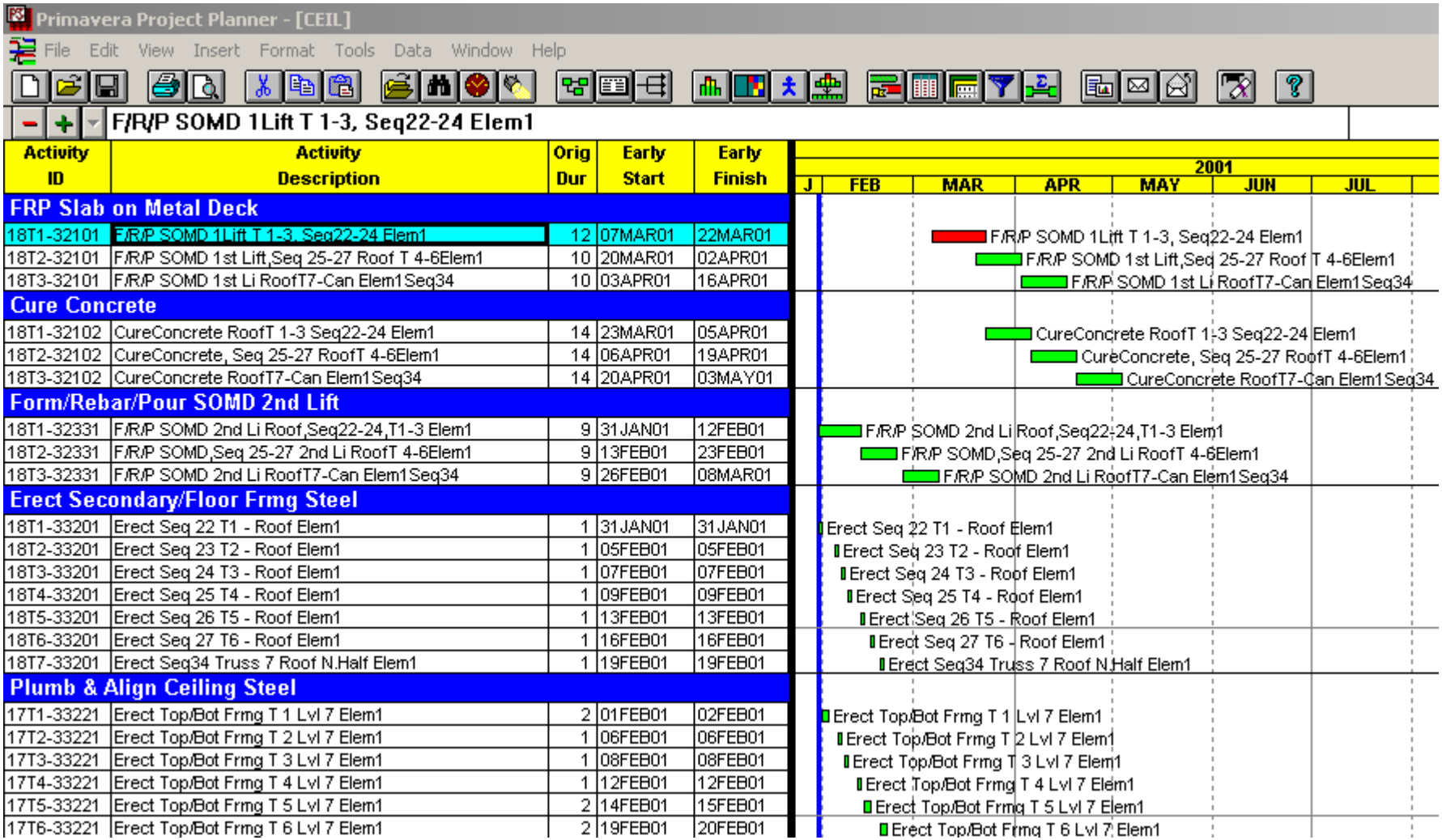


Review Design in 4D Viewer



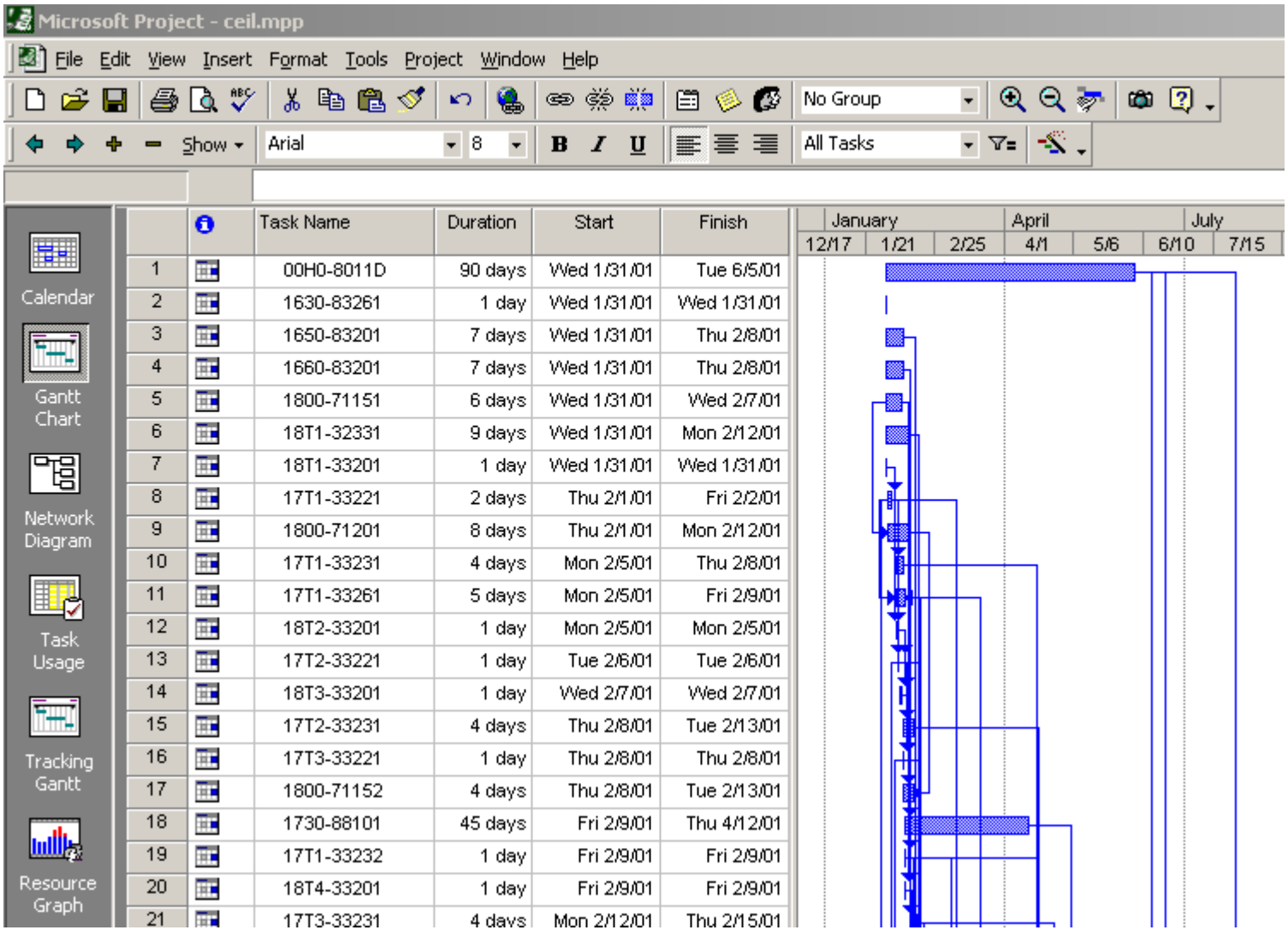
4D Model Taken on 3/25/2001 From 4DViewer

Review Schedule in Primavera



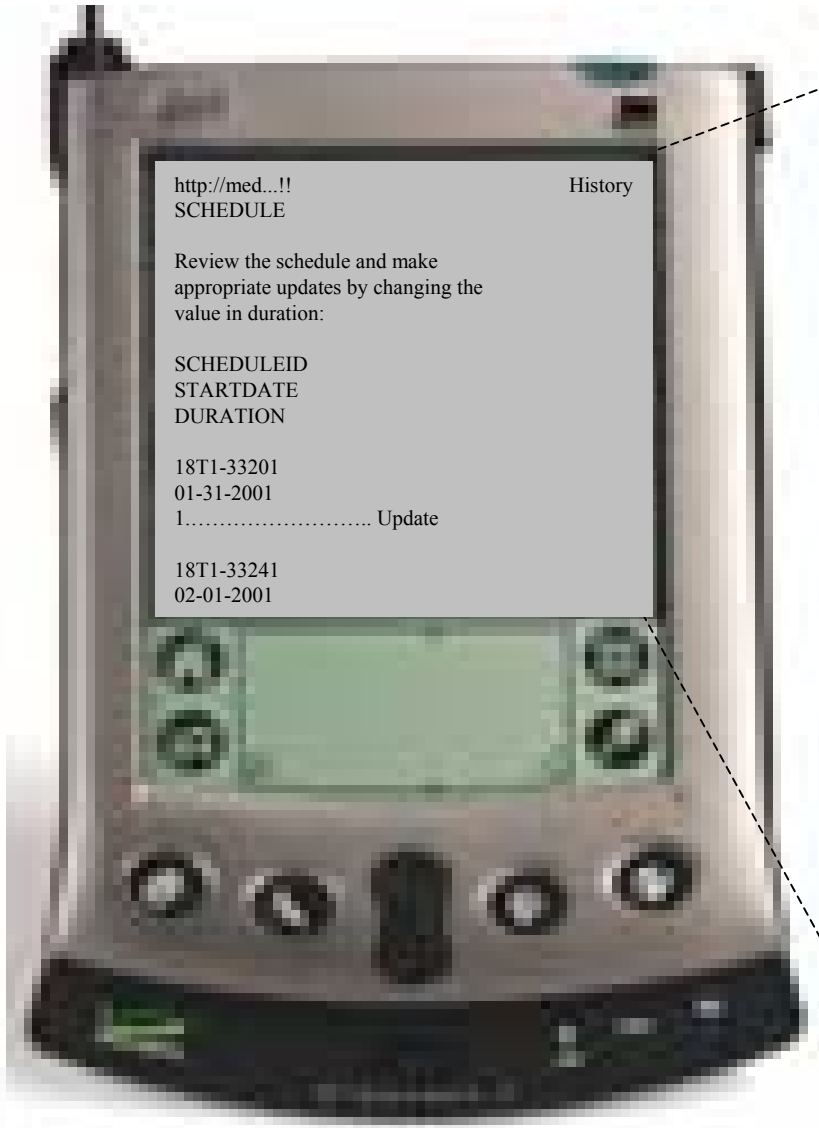
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
FRP Slab on Metal Deck				
18T1-32101	F/R/P SOMD 1Lift T 1-3, Seq22-24 Elem1	12	07MAR01	22MAR01
18T2-32101	F/R/P SOMD 1st Lift,Seq 25-27 Roof T 4-6Elem1	10	20MAR01	02APR01
18T3-32101	F/R/P SOMD 1st Li RoofT7-Can Elem1Seq34	10	03APR01	16APR01
Cure Concrete				
18T1-32102	CureConcrete RoofT 1-3 Seq22-24 Elem1	14	23MAR01	05APR01
18T2-32102	CureConcrete, Seq 25-27 RoofT 4-6Elem1	14	06APR01	19APR01
18T3-32102	CureConcrete RoofT7-Can Elem1Seq34	14	20APR01	03MAY01
Form/Rebar/Pour SOMD 2nd Lift				
18T1-32331	F/R/P SOMD 2nd Li Roof,Seq22-24,T1-3 Elem1	9	31JAN01	12FEB01
18T2-32331	F/R/P SOMD,Seq 25-27 2nd Li RoofT 4-6Elem1	9	13FEB01	23FEB01
18T3-32331	F/R/P SOMD 2nd Li RoofT7-Can Elem1Seq34	9	26FEB01	08MAR01
Erect Secondary/Floor Frmg Steel				
18T1-33201	Erect Seq 22 T1 - Roof Elem1	1	31JAN01	31JAN01
18T2-33201	Erect Seq 23 T2 - Roof Elem1	1	05FEB01	05FEB01
18T3-33201	Erect Seq 24 T3 - Roof Elem1	1	07FEB01	07FEB01
18T4-33201	Erect Seq 25 T4 - Roof Elem1	1	09FEB01	09FEB01
18T5-33201	Erect Seq 26 T5 - Roof Elem1	1	13FEB01	13FEB01
18T6-33201	Erect Seq 27 T6 - Roof Elem1	1	16FEB01	16FEB01
18T7-33201	Erect Seq34 Truss 7 Roof N.Half Elem1	1	19FEB01	19FEB01
Plumb & Align Ceiling Steel				
17T1-33221	Erect Top/Bot Frmg T 1 Lvl 7 Elem1	2	01FEB01	02FEB01
17T2-33221	Erect Top/Bot Frmg T 2 Lvl 7 Elem1	1	06FEB01	06FEB01
17T3-33221	Erect Top/Bot Frmg T 3 Lvl 7 Elem1	1	08FEB01	08FEB01
17T4-33221	Erect Top/Bot Frmg T 4 Lvl 7 Elem1	1	12FEB01	12FEB01
17T5-33221	Erect Top/Bot Frmg T 5 Lvl 7 Elem1	2	14FEB01	15FEB01
17T6-33221	Erect Top/Bot Frmg T 6 Lvl 7 Elem1	2	19FEB01	20FEB01

Review Schedule in Microsoft Project



	Task Name	Duration	Start	Finish
1	00H0-8011D	90 days	Wed 1/31/01	Tue 6/5/01
2	1630-83261	1 day	Wed 1/31/01	Wed 1/31/01
3	1650-83201	7 days	Wed 1/31/01	Thu 2/8/01
4	1660-83201	7 days	Wed 1/31/01	Thu 2/8/01
5	1800-71151	6 days	Wed 1/31/01	Wed 2/7/01
6	18T1-32331	9 days	Wed 1/31/01	Mon 2/12/01
7	18T1-33201	1 day	Wed 1/31/01	Wed 1/31/01
8	17T1-33221	2 days	Thu 2/1/01	Fri 2/2/01
9	1800-71201	8 days	Thu 2/1/01	Mon 2/12/01
10	17T1-33231	4 days	Mon 2/5/01	Thu 2/8/01
11	17T1-33261	5 days	Mon 2/5/01	Fri 2/9/01
12	18T2-33201	1 day	Mon 2/5/01	Mon 2/5/01
13	17T2-33221	1 day	Tue 2/6/01	Tue 2/6/01
14	18T3-33201	1 day	Wed 2/7/01	Wed 2/7/01
15	17T2-33231	4 days	Thu 2/8/01	Tue 2/13/01
16	17T3-33221	1 day	Thu 2/8/01	Thu 2/8/01
17	1800-71152	4 days	Thu 2/8/01	Tue 2/13/01
18	1730-88101	45 days	Fri 2/9/01	Thu 4/12/01
19	17T1-33232	1 day	Fri 2/9/01	Fri 2/9/01
20	18T4-33201	1 day	Fri 2/9/01	Fri 2/9/01
21	17T3-33231	4 days	Mon 2/12/01	Thu 2/15/01

View Schedule on Site



http://med...!! History

SCHEDULE

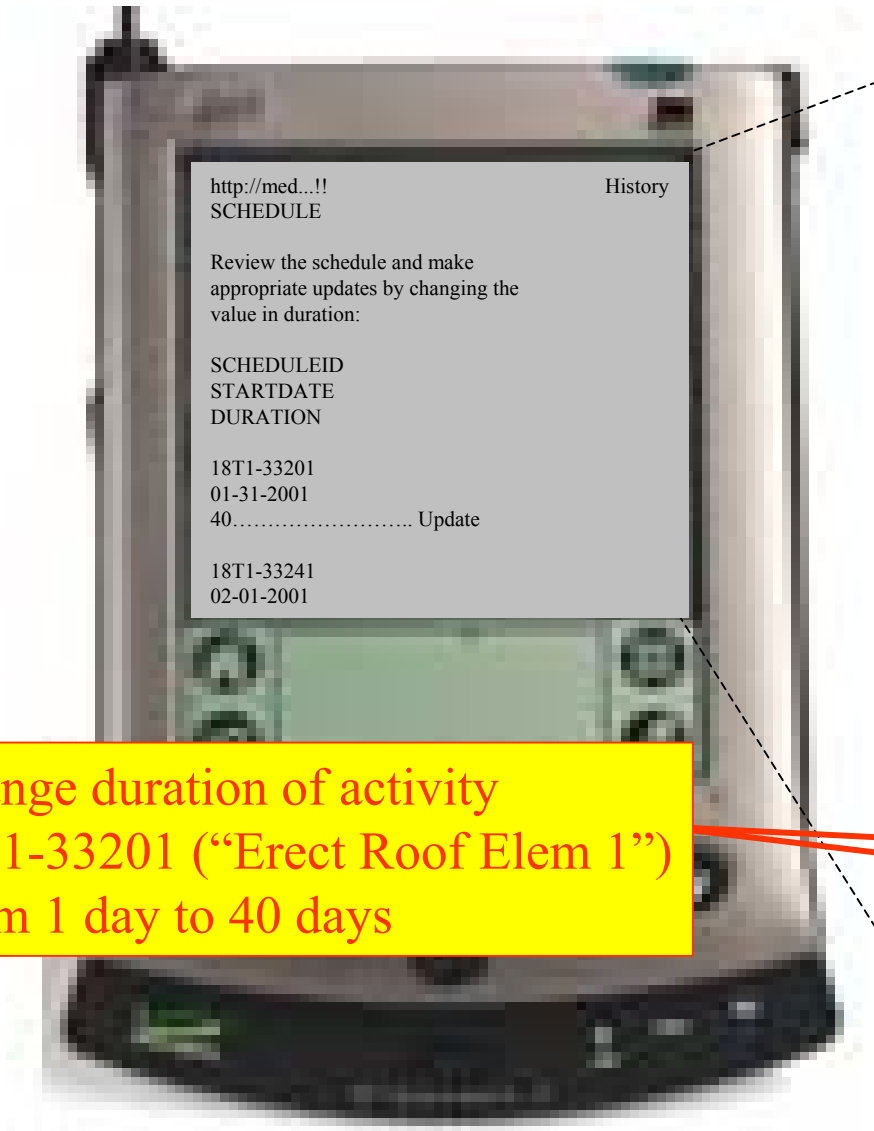
Review the schedule and make appropriate updates by changing the value in duration:

SCHEDULEID
STARTDATE
DURATION

18T1-33201
01-31-2001
1…….. Update

18T1-33241
02-01-2001

Modifying Schedule On-site



Change duration of activity 18T1-33201 (“Erect Roof Elem 1”) From 1 day to 40 days

http://med...!! History
SCHEDULE

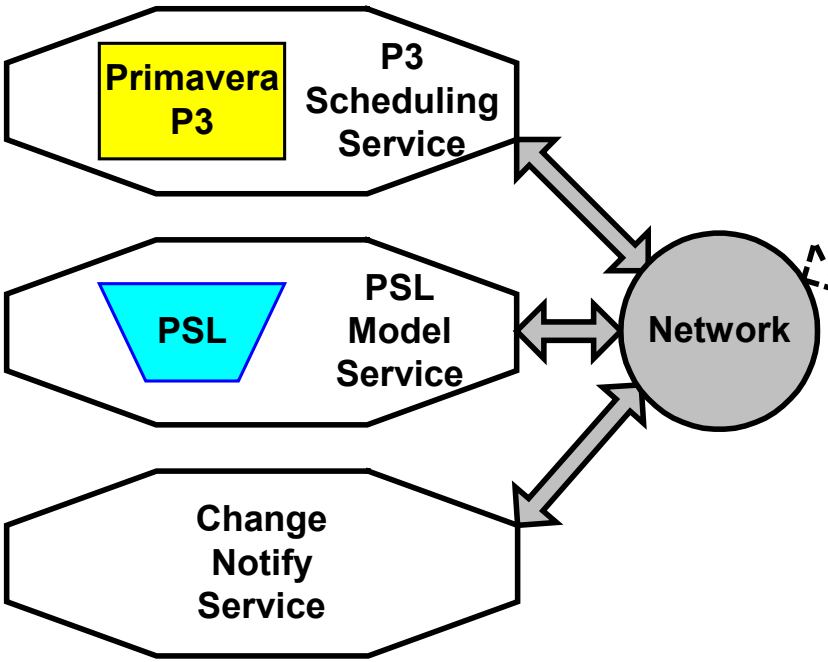
Review the schedule and make appropriate updates by changing the value in duration:

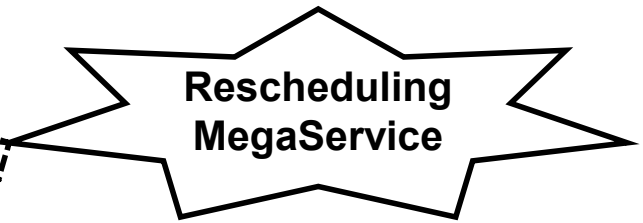
SCHEDULEID
STARTDATE
DURATION

18T1-33201
01-31-2001
40…….. Update

18T1-33241
02-01-2001

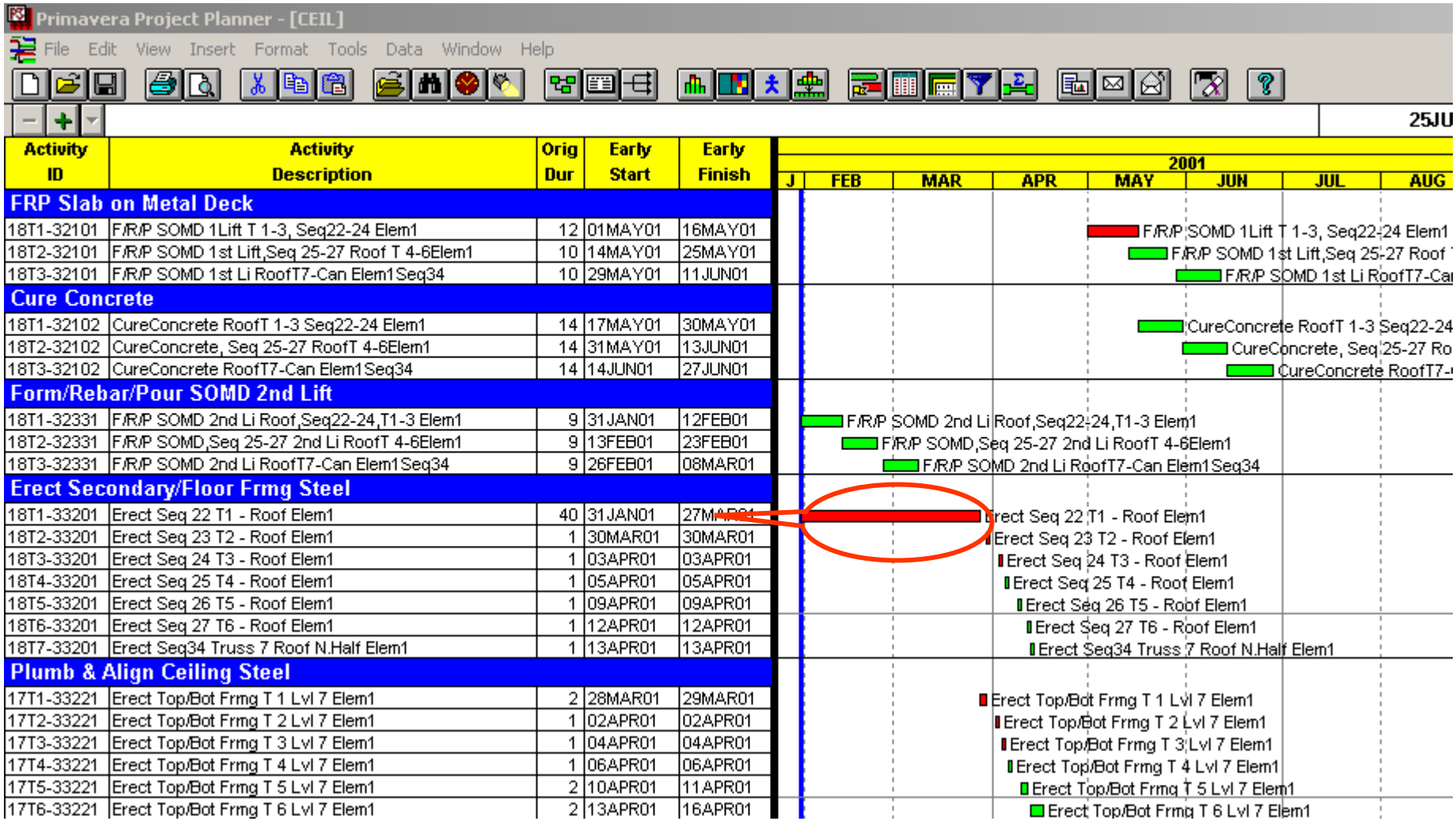
Invoke Rescheduling Megaservice





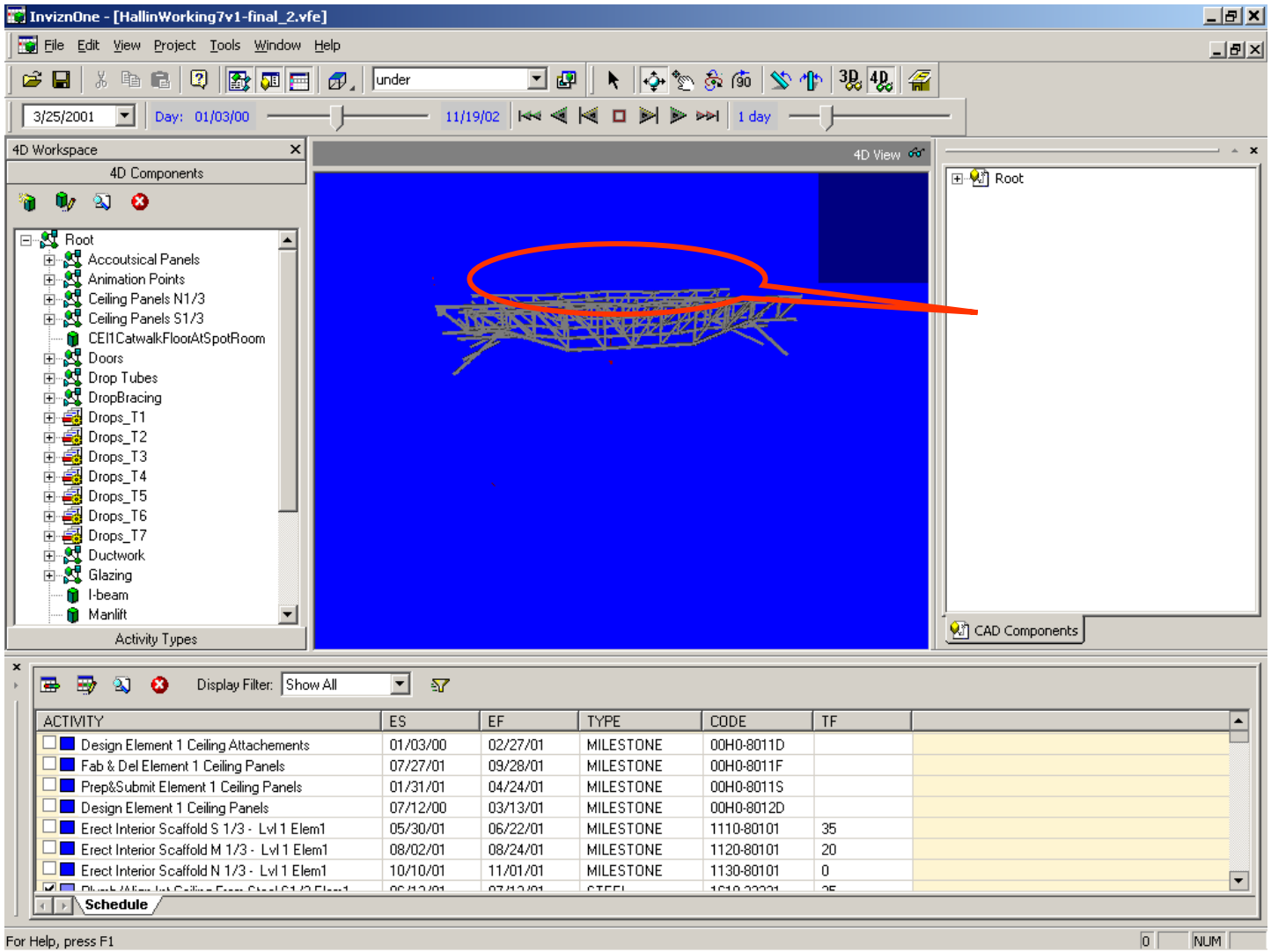

```
RescheduleService  {
   model = PSLModel(modelname, 'oracle-to-psl')
   new_model = P3Scheduling(model, 'reschedule')
   PSLModel(new_model, 'psl-to-oracle')
   ExcelService(new_model, 'show')
   ChangeNotify(modelname)
}
```


Review Modified Schedule in Primavera



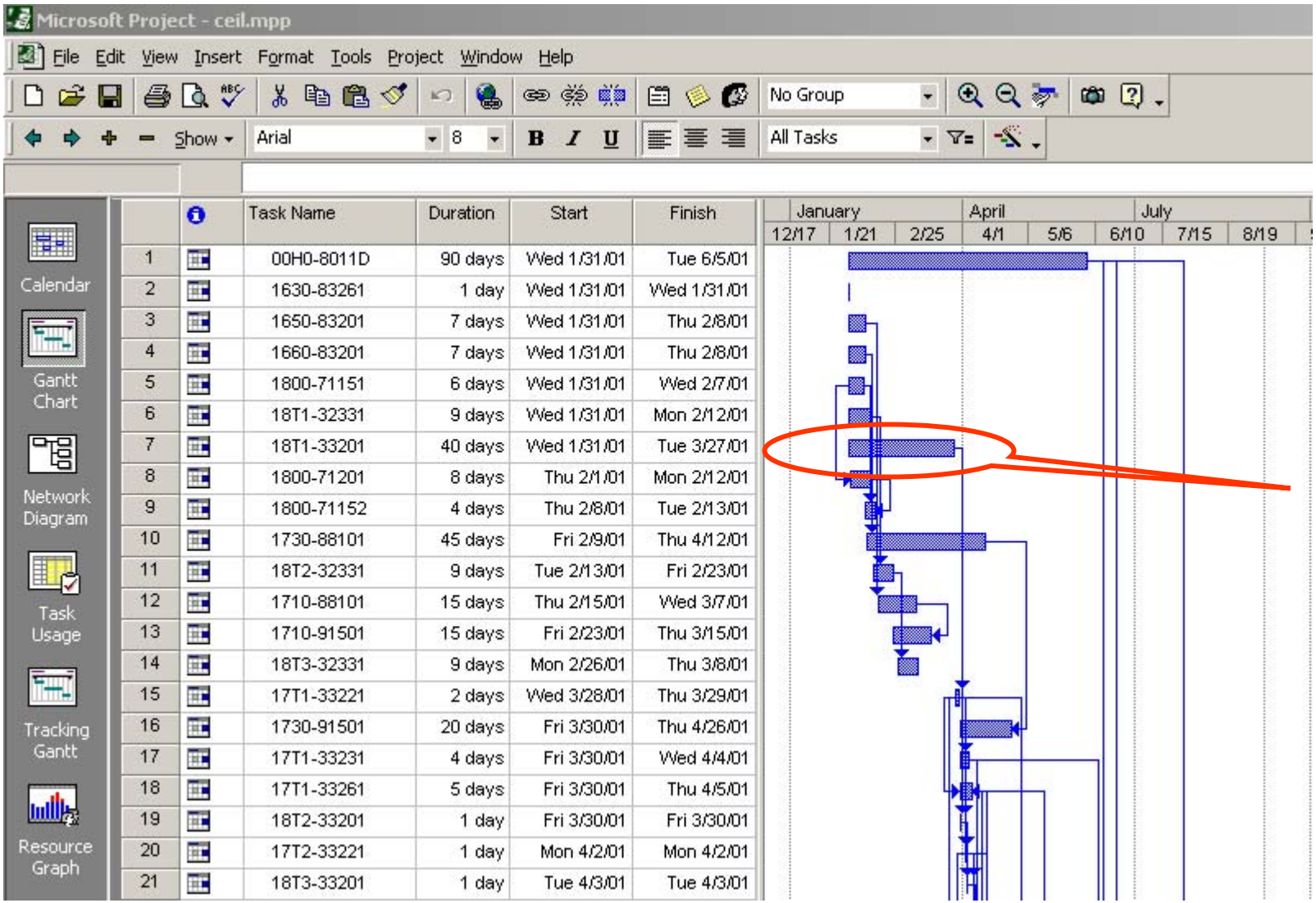
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
FRP Slab on Metal Deck				
18T1-32101	F/R/P SOMD 1Lift T 1-3, Seq22-24 Elem1	12	01MAY01	16MAY01
18T2-32101	F/R/P SOMD 1st Lift,Seq 25-27 Roof T 4-6Elem1	10	14MAY01	25MAY01
18T3-32101	F/R/P SOMD 1st Li RoofT7-Can Elem1 Seq34	10	29MAY01	11JUN01
Cure Concrete				
18T1-32102	CureConcrete RoofT 1-3 Seq22-24 Elem1	14	17MAY01	30MAY01
18T2-32102	CureConcrete, Seq 25-27 RoofT 4-6Elem1	14	31MAY01	13JUN01
18T3-32102	CureConcrete RoofT7-Can Elem1 Seq34	14	14JUN01	27JUN01
Form/Rebar/Pour SOMD 2nd Lift				
18T1-32331	F/R/P SOMD 2nd Li Roof,Seq22-24,T1-3 Elem1	9	31JAN01	12FEB01
18T2-32331	F/R/P SOMD,Seq 25-27 2nd Li RoofT 4-6Elem1	9	13FEB01	23FEB01
18T3-32331	F/R/P SOMD 2nd Li RoofT7-Can Elem1 Seq34	9	26FEB01	08MAR01
Erect Secondary/Floor Frmg Steel				
18T1-33201	Erect Seq 22 T1 - Roof Elem1	40	31JAN01	27MAR01
18T2-33201	Erect Seq 23 T2 - Roof Elem1	1	30MAR01	30MAR01
18T3-33201	Erect Seq 24 T3 - Roof Elem1	1	03APR01	03APR01
18T4-33201	Erect Seq 25 T4 - Roof Elem1	1	05APR01	05APR01
18T5-33201	Erect Seq 26 T5 - Roof Elem1	1	09APR01	09APR01
18T6-33201	Erect Seq 27 T6 - Roof Elem1	1	12APR01	12APR01
18T7-33201	Erect Seq34 Truss 7 Roof N.Half Elem1	1	13APR01	13APR01
Plumb & Align Ceiling Steel				
17T1-33221	Erect Top/Bot Frmg T 1 Lvl 7 Elem1	2	28MAR01	29MAR01
17T2-33221	Erect Top/Bot Frmg T 2 Lvl 7 Elem1	1	02APR01	02APR01
17T3-33221	Erect Top/Bot Frmg T 3 Lvl 7 Elem1	1	04APR01	04APR01
17T4-33221	Erect Top/Bot Frmg T 4 Lvl 7 Elem1	1	06APR01	06APR01
17T5-33221	Erect Top/Bot Frmg T 5 Lvl 7 Elem1	2	10APR01	11APR01
17T6-33221	Erect Top/Bot Frmg T 6 Lvl 7 Elem1	2	13APR01	16APR01

Review Modified Design in 4D Viewer



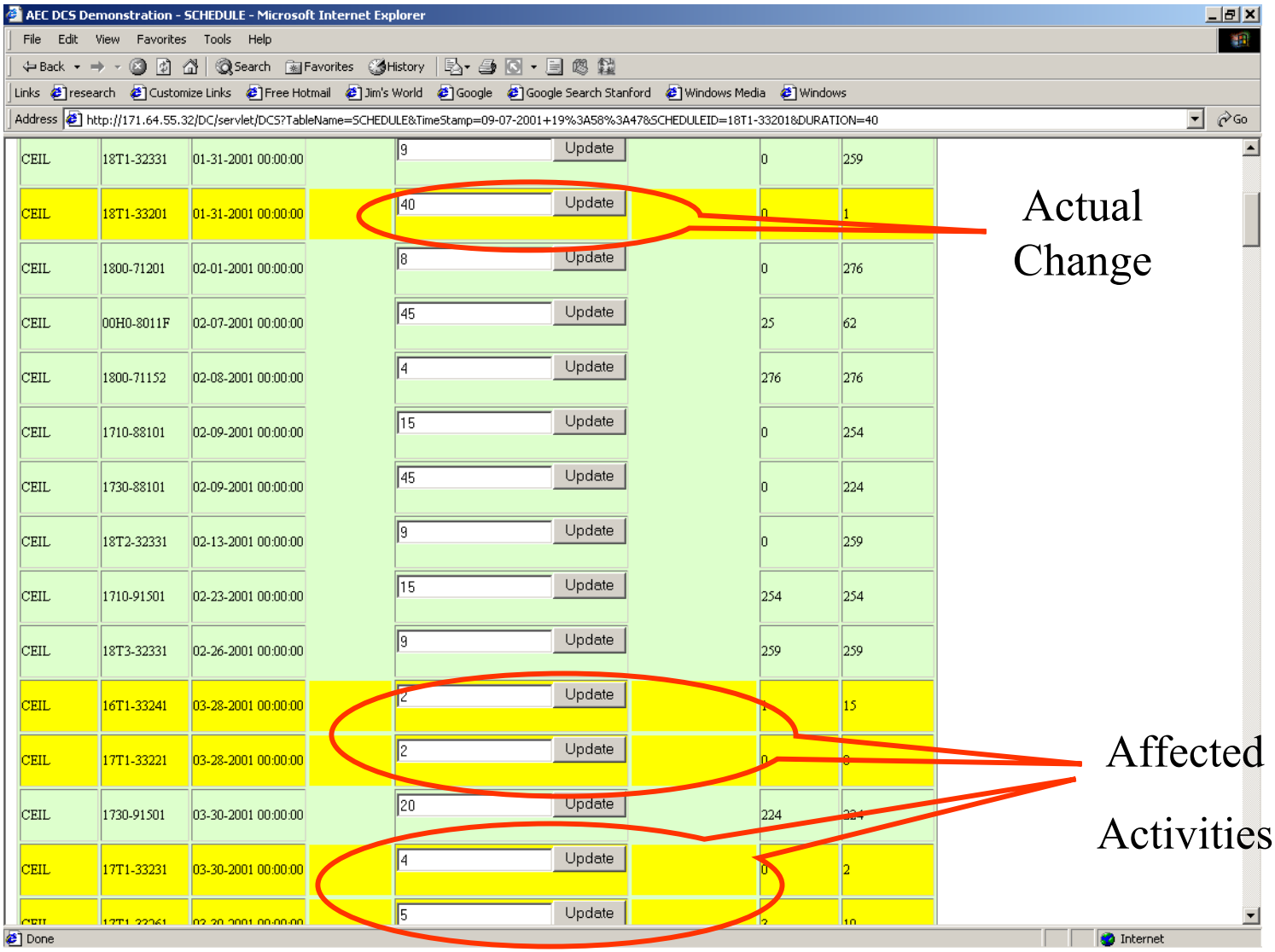
4D Model Taken at 3/25/2001 From 4DViewer

Review Modified Schedule in Microsoft Project

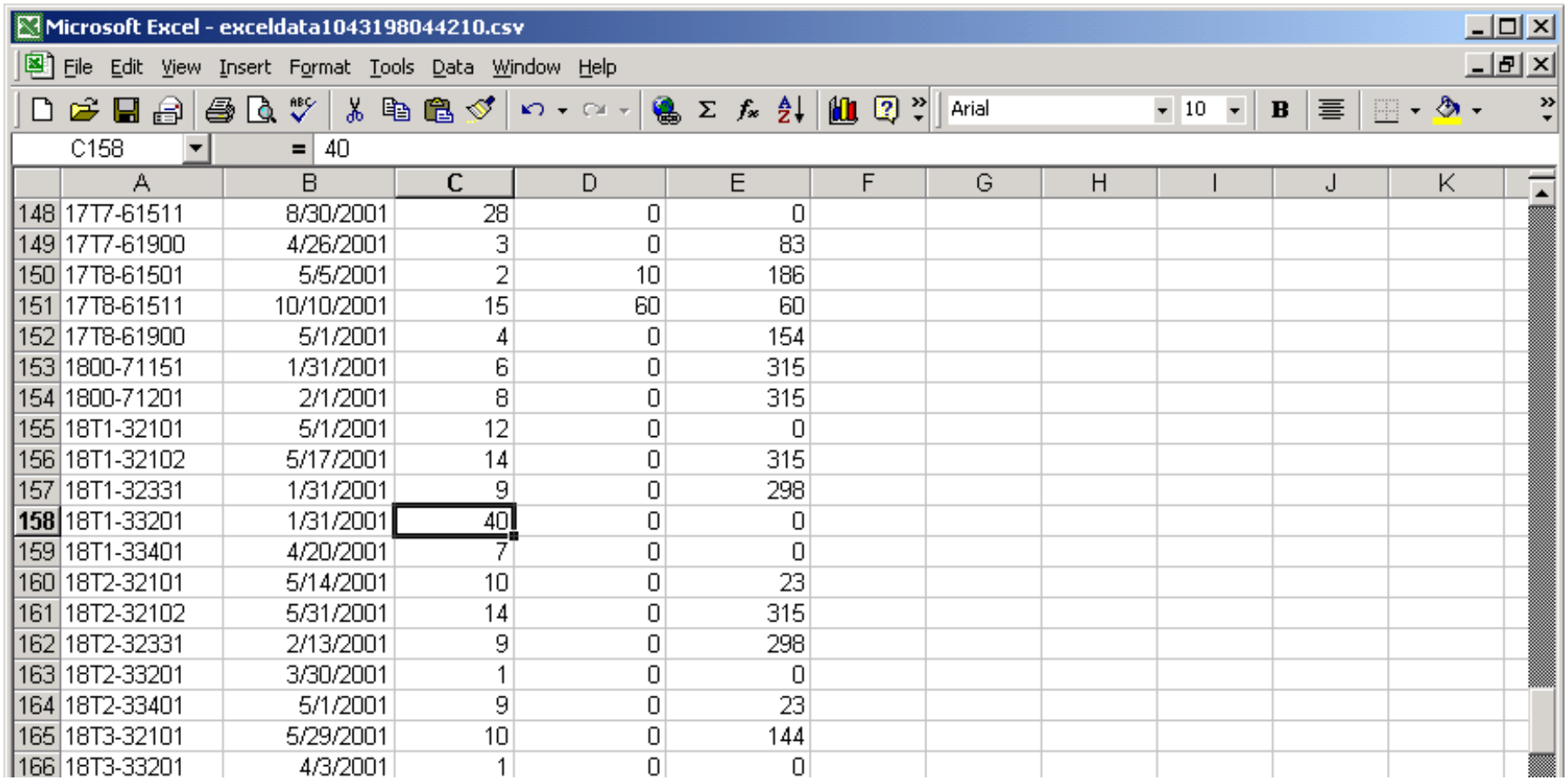


	Task Name	Duration	Start	Finish
1	00H0-8011D	90 days	Wed 1/31/01	Tue 6/5/01
2	1630-83261	1 day	Wed 1/31/01	Wed 1/31/01
3	1650-83201	7 days	Wed 1/31/01	Thu 2/8/01
4	1660-83201	7 days	Wed 1/31/01	Thu 2/8/01
5	1800-71151	6 days	Wed 1/31/01	Wed 2/7/01
6	18T1-32331	9 days	Wed 1/31/01	Mon 2/12/01
7	18T1-33201	40 days	Wed 1/31/01	Tue 3/27/01
8	1800-71201	8 days	Thu 2/1/01	Mon 2/12/01
9	1800-71152	4 days	Thu 2/8/01	Tue 2/13/01
10	1730-88101	45 days	Fri 2/9/01	Thu 4/12/01
11	18T2-32331	9 days	Tue 2/13/01	Fri 2/23/01
12	1710-88101	15 days	Thu 2/15/01	Wed 3/7/01
13	1710-91501	15 days	Fri 2/23/01	Thu 3/15/01
14	18T3-32331	9 days	Mon 2/26/01	Thu 3/8/01
15	17T1-33221	2 days	Wed 3/28/01	Thu 3/29/01
16	1730-91501	20 days	Fri 3/30/01	Thu 4/26/01
17	17T1-33231	4 days	Fri 3/30/01	Wed 4/4/01
18	17T1-33261	5 days	Fri 3/30/01	Thu 4/5/01
19	18T2-33201	1 day	Fri 3/30/01	Fri 3/30/01
20	17T2-33221	1 day	Mon 4/2/01	Mon 4/2/01
21	18T3-33201	1 day	Tue 4/3/01	Tue 4/3/01

Review Changed Activities in Desktop Browser



Review Modified Schedule in Excel



	A	B	C	D	E	F	G	H	I	J	K
148	17T7-61511	8/30/2001	28	0	0						
149	17T7-61900	4/26/2001	3	0	83						
150	17T8-61501	5/5/2001	2	10	186						
151	17T8-61511	10/10/2001	15	60	60						
152	17T8-61900	5/1/2001	4	0	154						
153	1800-71151	1/31/2001	6	0	315						
154	1800-71201	2/1/2001	8	0	315						
155	18T1-32101	5/1/2001	12	0	0						
156	18T1-32102	5/17/2001	14	0	315						
157	18T1-32331	1/31/2001	9	0	298						
158	18T1-33201	1/31/2001	40	0	0						
159	18T1-33401	4/20/2001	7	0	0						
160	18T2-32101	5/14/2001	10	0	23						
161	18T2-32102	5/31/2001	14	0	315						
162	18T2-32331	2/13/2001	9	0	298						
163	18T2-33201	3/30/2001	1	0	0						
164	18T2-33401	5/1/2001	9	0	23						
165	18T3-32101	5/29/2001	10	0	144						
166	18T3-33201	4/3/2001	1	0	0						