PSL Quarterly Progress Report

Project Title: Process Specification and Simulation
Date: September 30, 2001
Principal Investigator: Kincho H. Law, Stanford University
Period Covered: July 1, 2001 – September 30, 2001

Project Objectives

The proposed project is intended to be a feasibility study to evaluate the process specification language (PSL) and a simulation query language (SimQL) with application to project and workflow management. This proposed joint research effort includes:

- to evaluate the potential of the Process Specification Language (PSL) for the planning and modeling activities in a project
- to evaluate the adequacy of the Process Specification Language (PSL) as an interchange definition language to support process-oriented simulation
- to evaluate the applicability of SimQL, a simulation query language, for practical engineering problems
- to develop an integration framework using PSL and SimQL for process-oriented simulation

Our long-term goal is to develop a distributed network-based framework to integrate process specification and modeling and virtual simulations of project activities. To facilitate this research, we use Vite, which is originally developed at Stanford's Center for Integrated Facility Engineering as a benchmarking application for the evaluation of PSL and SimQL.

Progress and Results

Our first goal in this project is to evaluate PSL as process specification interchange standard using Vite as a benchmark application. Vite is a project and organization modeling system designed to assist in developing organizational structures and identifying potential problems with project cost, time, or quality. It takes traditionally qualitative organizational management theory and builds a model that incorporates rough quantitative measures. As for this investigation, we have built a sample demonstration using PSL as an interchange format to exchange information among Primavera's P3, Microsoft Project 2000, 4DViewer and Vite. Primavera's P3 and Microsoft Project 2000 are project scheduling software widely used in the construction industry. 4D Viewer is an application developed by 4D research group at Stanford University, which could dynamically display the construction progress. The translation process among Primavera P3, Microsoft Project and Vite using PSL is summarized as shown in Figure 1.

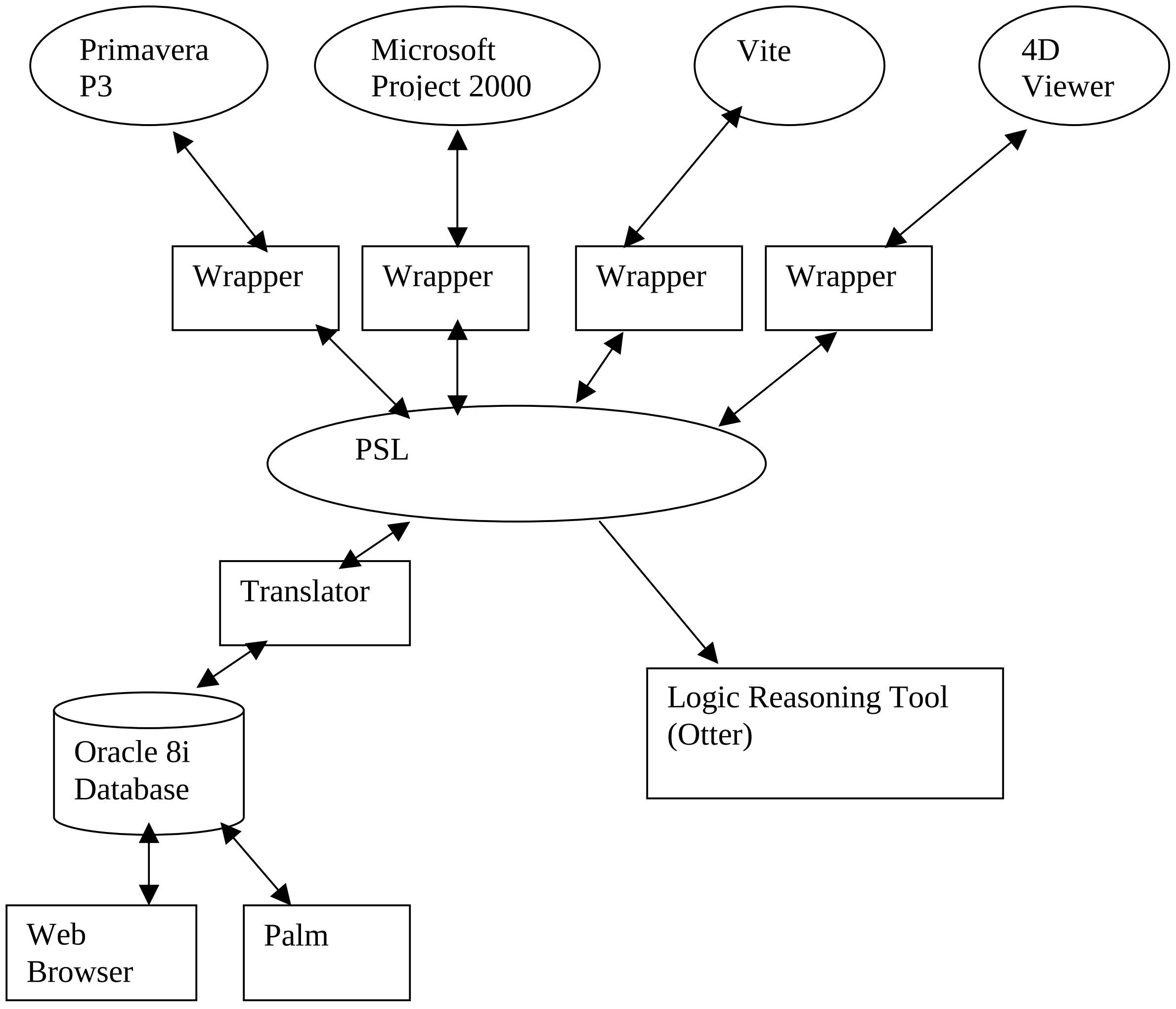


Figure 1: PSL in the Information Exchange

As shown in figure 1, we have also built translator between PSL and Oracle Database, so that project information could be viewed and updated on any web browser and palm. Beyond that, we link PSL file with logic reasoning tool so that we can reason on PSL knowledge. In summary, three basic tasks have been performed during this report period.

- We select some widely used applications in construction industry, and build PSL wrapper for each of those applications. So that those applications are PSL compliant and could interoperate with each other.

- We also build translator between PSL and oracle database. So that project manager could view and update project information on site using web browser or palm. Here we test our prototype system on Mortenson Ceiling Project, which is a portion of the construction of Walt Disney Concert Hall.

- We have begun an initial investigation on the reasoning power of PSL.

PSL Wrapper

To exchange project information among different construction applications, we need to build a wrapper for each application, which could retrieve the information out from application and convert it into PSL format, and could also parse the information out from PSL file and feed it back into application.

To exchange project information, first we need to map the concepts in different applications into PSL ontology. The table below (Table 1) shows some terms in P3 and PSL, which are related with activity relationship.

Table 1: Terms in P3 and PSL about activity relationship

Concepts in P3	PSL Ontology
Successor Predecessor	Successor Follows after-start after-start-delay …………..

For example, activity B is the successor of activity A in construction project P in P3. The time lag is 3 days, and relationship type is FinishToStart, which is illustrated in figure 8.

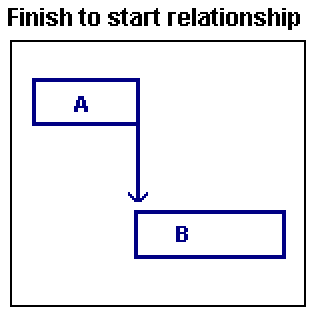


Figure 2. Successor relationship in P3

If we translate the successor concepts into PSL ontology, we will have:

(activity-occurrence A)
(activity-occurrence B)
(subactivity-occurrence A P)
(subactivity-occurrence B P)
(after-start A B P)
(after-start-delay A B 3)

The basic process of PSL based project information exchange could be illustrated in picture 3.

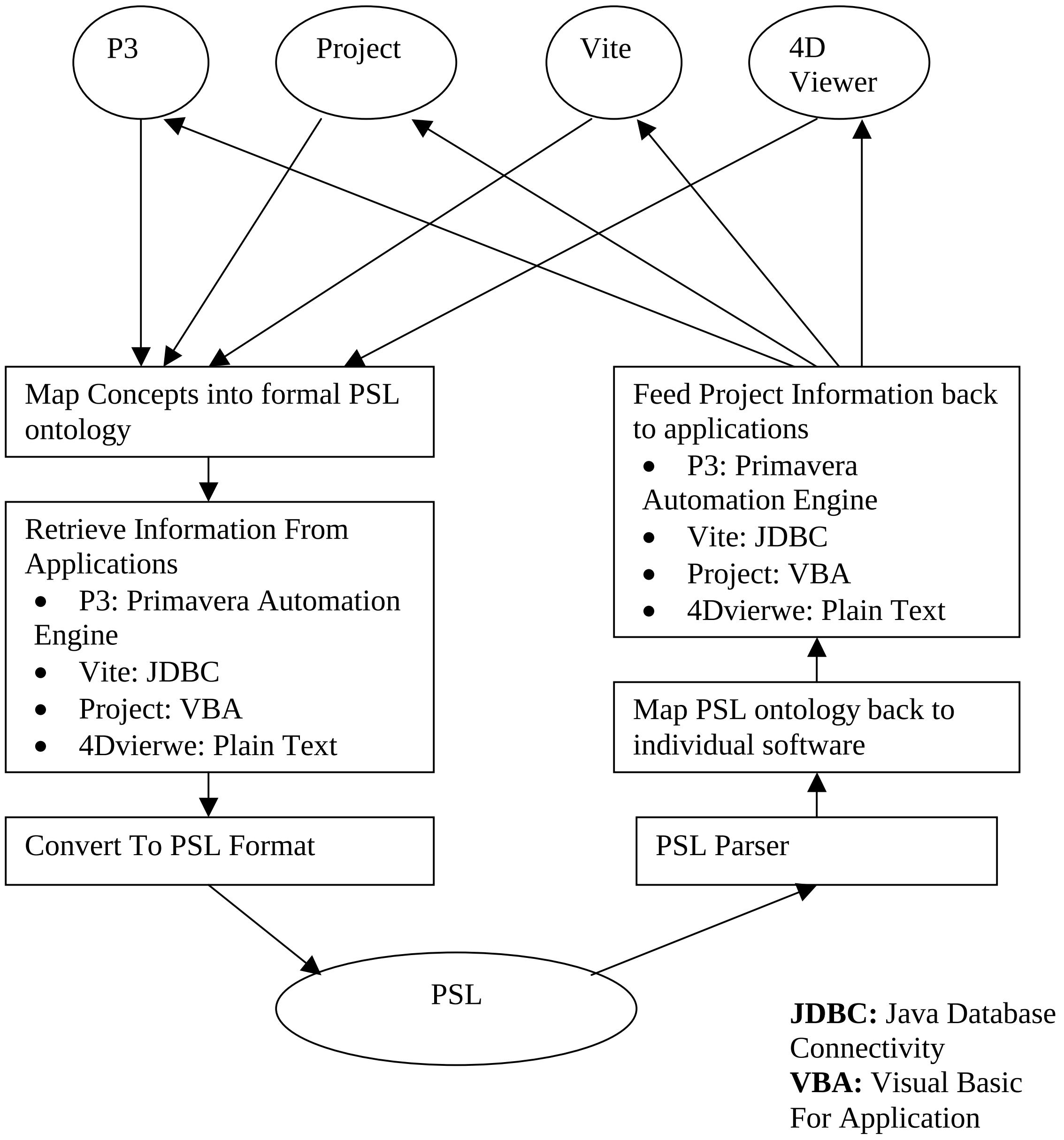
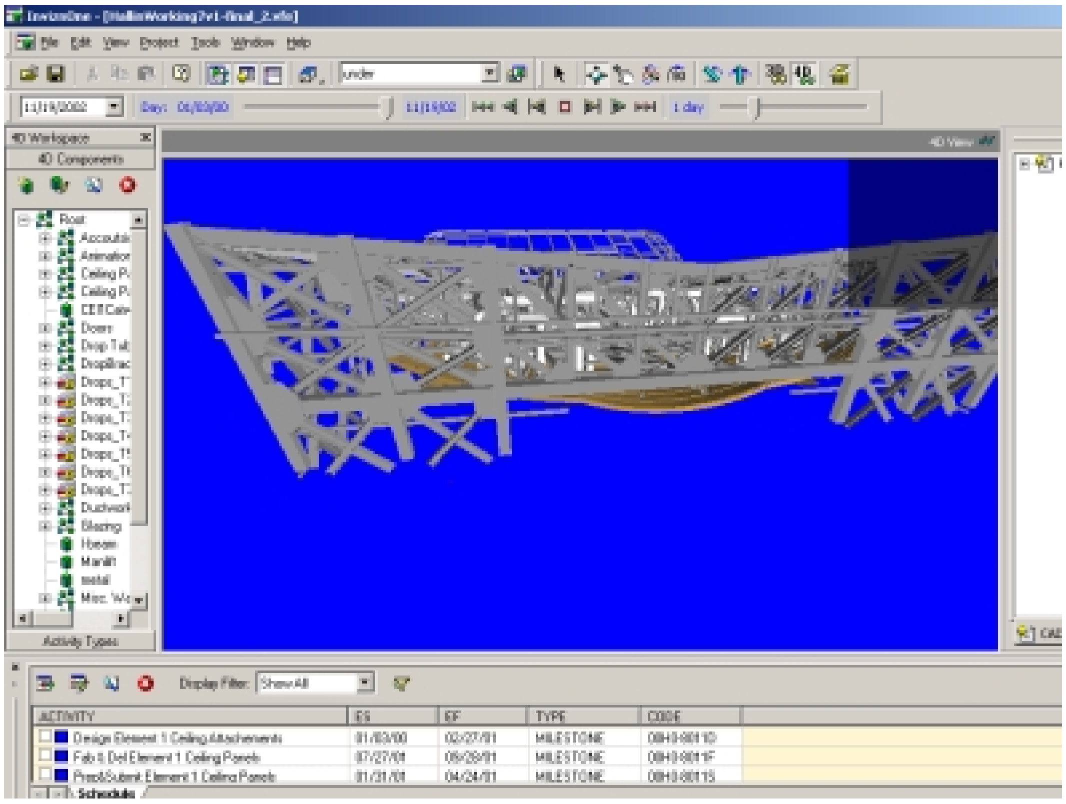

P3
Project
Vite
4D Viewer
Map Concepts into formal PSL ontology
Retrieve Information From Applications
• P3: Primavera Automation Engine
• Vite: JDBC
• Project: VBA
• 4Dvierwe: Plain Text
Convert To PSL Format
PSL
PSL Parser
Map PSL ontology back to individual software
Feed Project Information back to applications
• P3: Primavera Automation Engine
• Vite: JDBC
• Project: VBA
• 4Dvierwe: Plain Text
JDBC: Java Database Connectivity
VBA: Visual Basic For Application

Figure 3: PSL Wrapper

Information Exchange Among Vite, P3 and MS Project

We select Mortenson Ceiling Project to demonstrate the translation. Mortenson Ceiling Project is a portion of the construction of the Walt Disney Concert Hall, built by Mortenson Construction, and designed by Frank O.Gehry & Associates. The curvilinear ceiling for a major concert hall is designed as light gage steel, hung from the trusses, as shown in figure 4.



ACTIVITY	ES	EF	TYPE	CODE
Design Element 1 Ceiling Attachements	01/03/00	02/27/01	MILESTONE	08H3-0011D
Fab & Del Element 1 Ceiling Panels	07/27/01	09/28/01	MILESTONE	08H3-0011F
Prep&Submit Element 1 Ceiling Panels	01/31/01	04/24/01	MILESTONE	08H3-00115

Figure 4. Mortenson Ceiling Project in 4DViewer

In our prototype system, we use oracle database as our backbone system. Through oracle database, on-site personnel can view and update project information using a PDA or a desktop browser (Figure 9). Applications such as P3, Project, 4DViewer and Vite could also interoperate with each other through a process interchange standard (PSL).

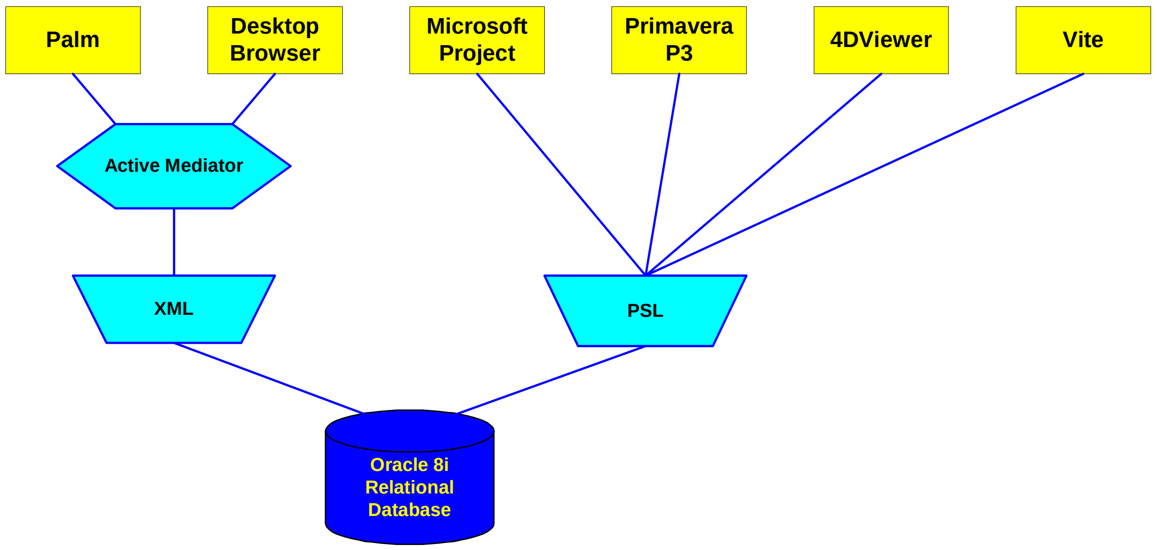
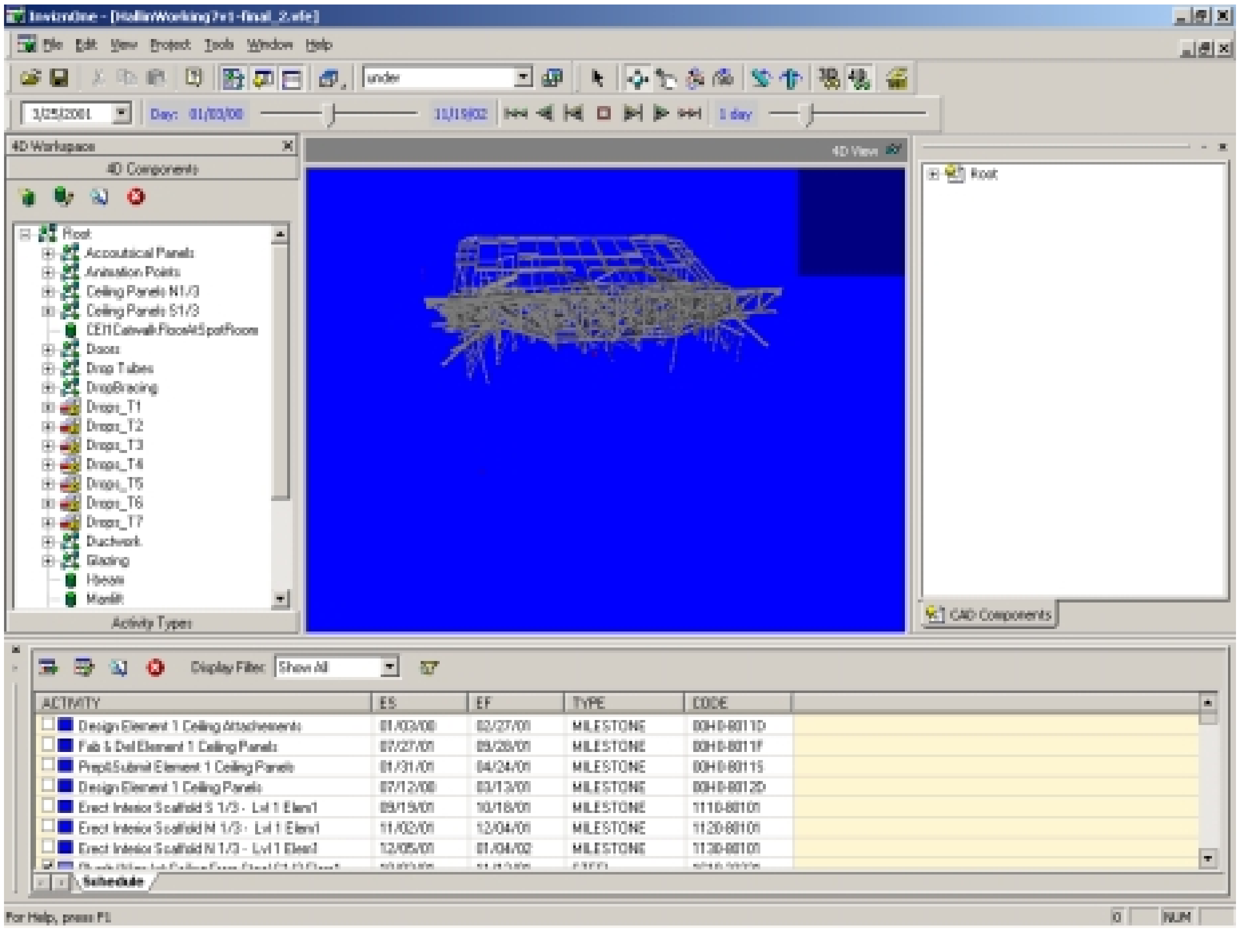


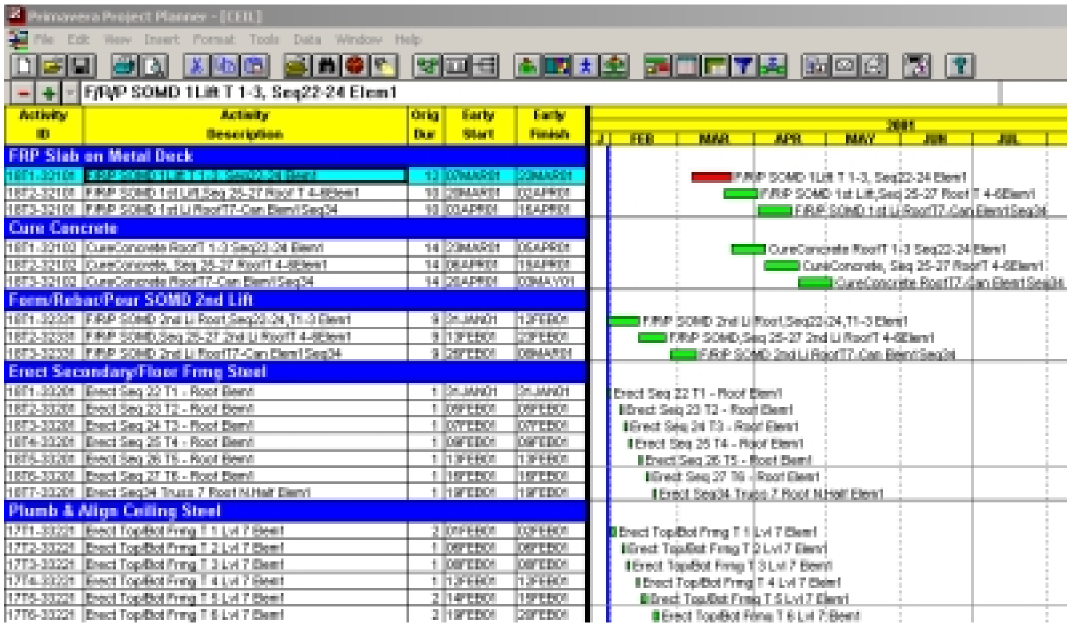
Figure 5. Architecture of the prototype system

Figure 6 is the 4D Model of Mortenson Ceiling Project taken on 3/25/2001 from 4D Viewer. Figure 7 and 8 show the Original Gantt Chart of Mortenson Ceiling Project in Primavera P3 and Microsoft Project. On site personnel can view and update project information through palm or web browser, as shown in Figure 9. Figure 10 and 12 show the modified Gantt Chart in Primavera P3 and Microsoft Project 2000. Figure 11 show the modified 4D Model of Mortenson Ceiling Project taken on 3/25/2001 from 4D Viewer. As shown in Figure 13, project manager can view the updated project information on web browser or any other e-machine.



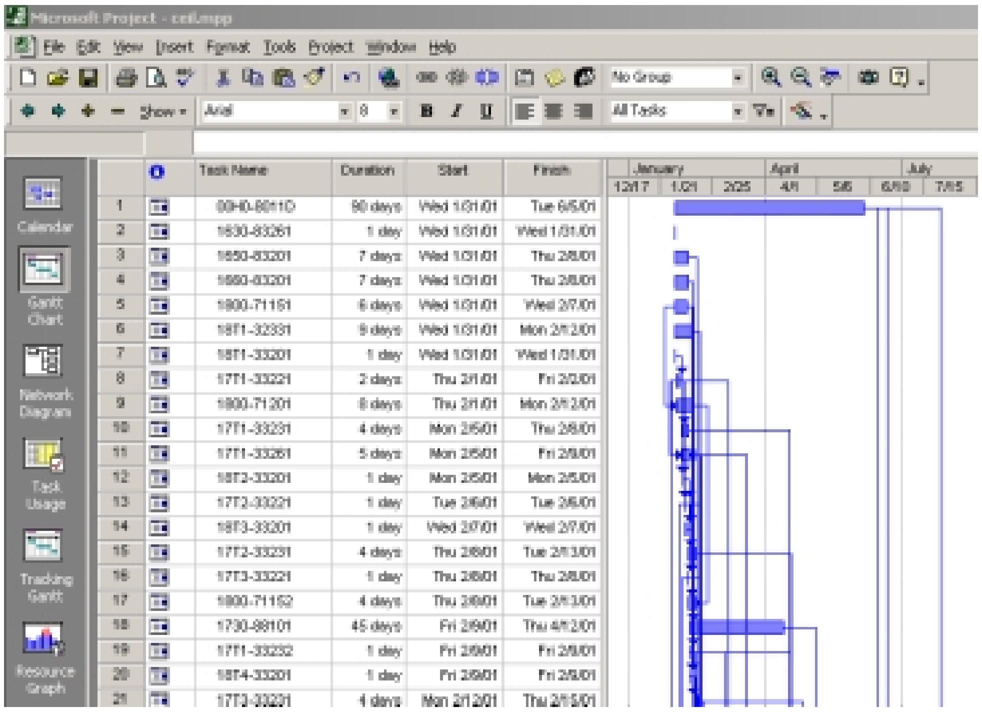
ACTIVITY	ES	EF	TYPE	CODE
☐ Design Element 1 Ceiling Attachements	01/03/00	02/27/01	MILESTONE	00H0-8011D
☐ Fab & Del Element 1 Ceiling Panels	07/27/01	09/28/01	MILESTONE	00H0-8011F
☐ Prep&Submit Element 1 Ceiling Panels	01/31/01	04/24/01	MILESTONE	00H0-80115
☐ Design Element 1 Ceiling Panels	07/12/00	03/13/01	MILESTONE	00H0-8012D
☐ Erect Interior Scaffold S 1/3 - Lvl 1 Elem1	09/19/01	10/18/01	MILESTONE	1110-80101
☐ Erect Interior Scaffold M 1/3 - Lvl 1 Elem1	11/02/01	12/04/01	MILESTONE	1120-80101
☐ Erect Interior Scaffold N 1/3 - Lvl 1 Elem1	12/05/01	01/04/02	MILESTONE	1130-80101
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 6. 4D Model Taken on 3/25/2001 From 4Dviewer


Primavera Project Planner - [CEIL]
File Edit View Insert Format Tools Data Window Help
F/RP SOMD 1Lift T 1-3, Seq22-24 Elem1
2001
J FEB MAR APR MAY JUN JUL

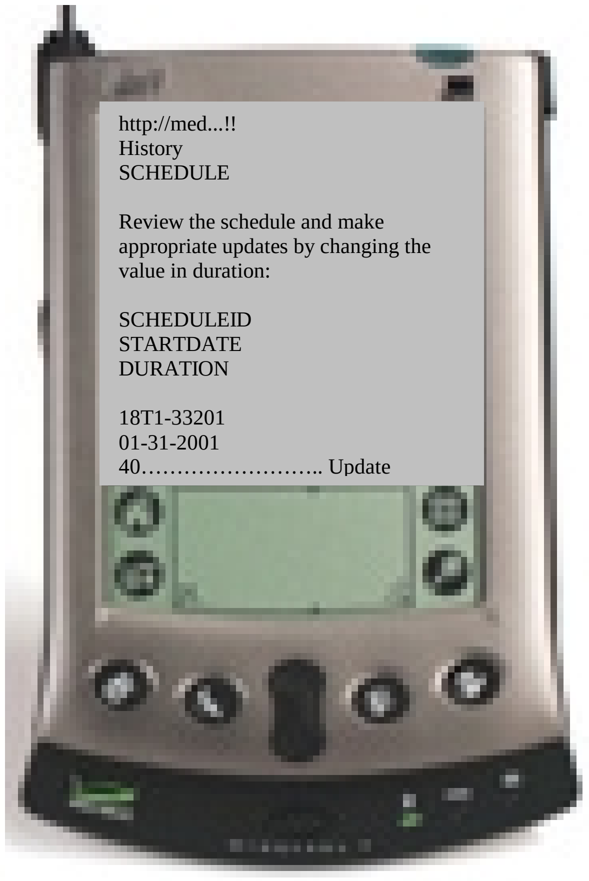
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
FRP Slab on Metal Deck				
18T1-32101	F/RP SOMD 1Lift T 1-3, Seq22-24 Elem1	12	07MAR01	22MAR01
18T2-32101	F/RP SOMD 1st Lift,Seq 25-27 Roof T 4-6Elem1	10	23MAR01	02APR01
18T3-32101	F/RP SOMD 1st Li RoofT7-Can Elem1Seq34	10	03APR01	16APR01
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				
18T1-32201	F/RP SOMD 2nd Li Roof,Seq22-24,T1-3 Elem1	9	31JAN01	12FEB01
18T2-32201	F/RP SOMD,Seq 25-27 2nd Li RoofT 4-6Elem1	9	13FEB01	23FEB01
18T3-32201	F/RP 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	15FEB01	15FEB01
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

Figure 7. Original Gantt chart in Primavera P3



	Task Name	Duration	Start	Finish
1	00H0-80110	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	1800-71161	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	1800-71162	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	17T3-33221	4 days	Mon 2/12/01	Thu 2/15/01

Figure 8. Original Gantt Chart in MS Project (Generated from PSL file)



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

http://171...!!   History

SCHEDULE

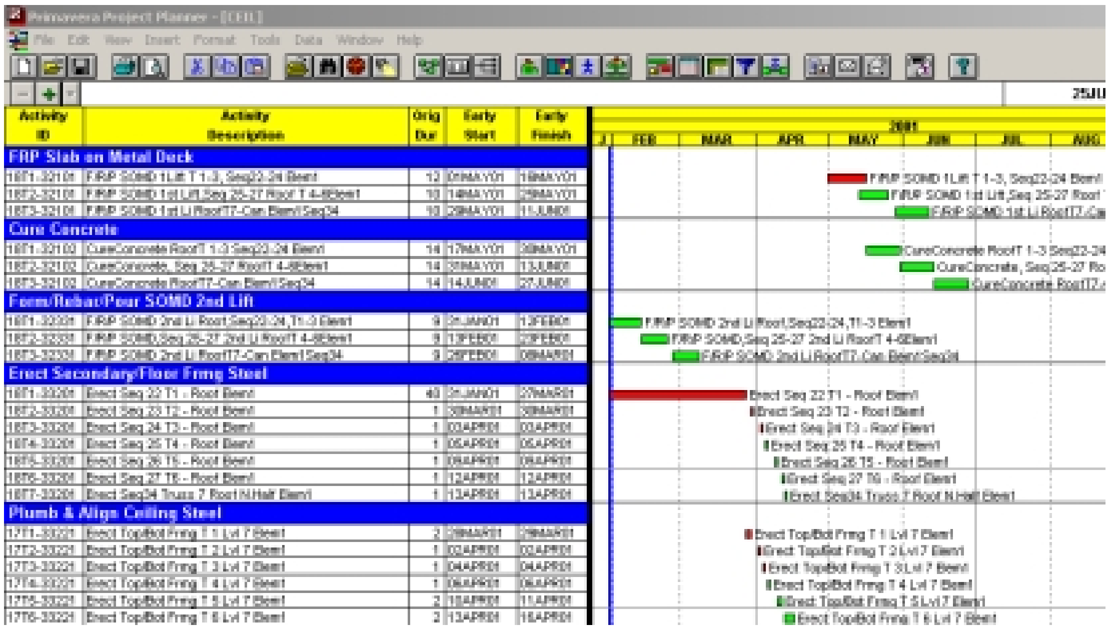
Review the schedule and make appropriate updates by changing the value in duration:

SCHEDULEID
STARTDATE
DURATION

18T1-33201
01-31-2001
40…………………….. Update

18T1-33241

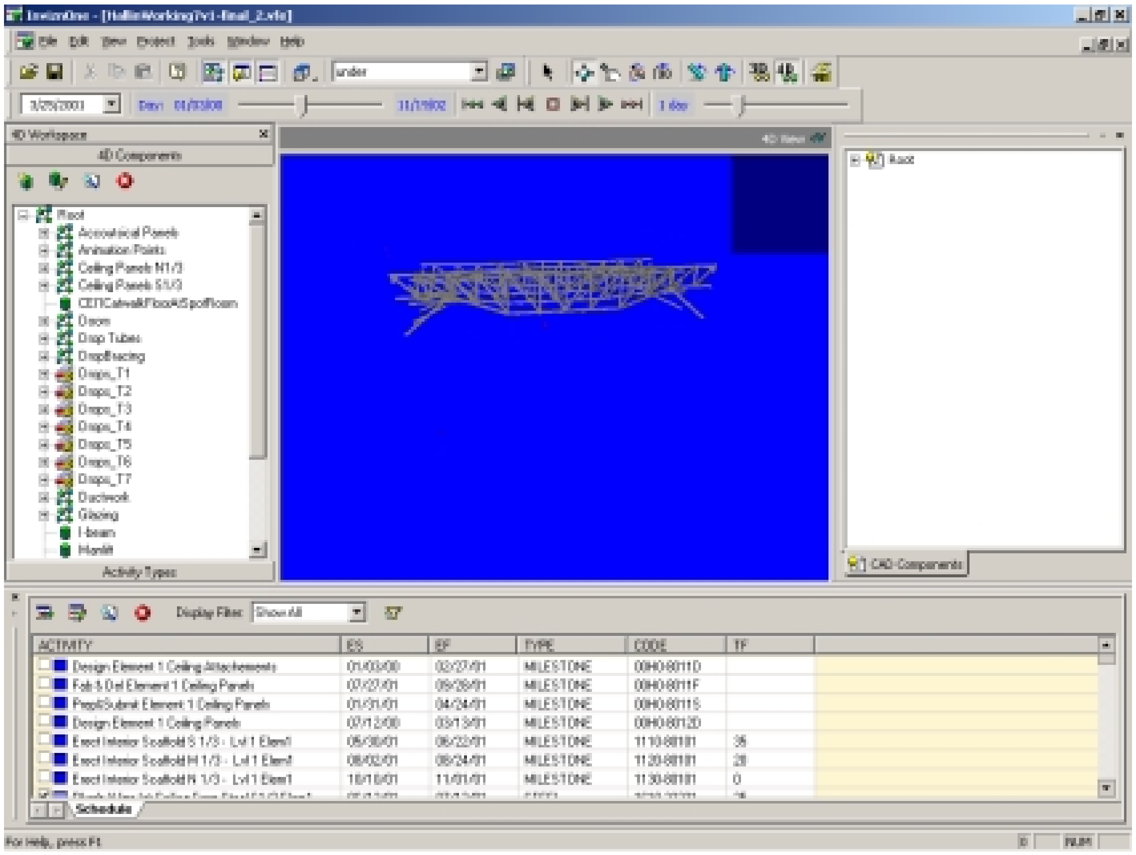
Figure 9. View and Update Project Information on Palm



Primavera Project Planner - [CEIL]
File Edit View Insert Format Tools Data Window Help
2001
JAN FEB MAR APR MAY JUN JUL AUG

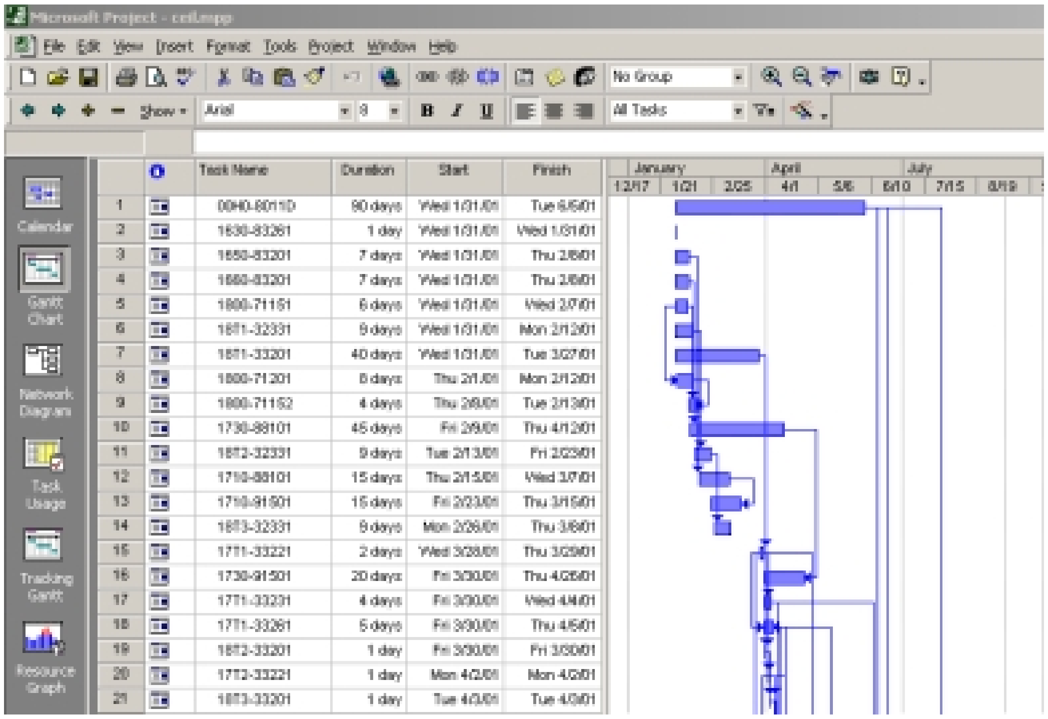
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
FRP Slab on Metal Deck				
18T1-32101	F/RP SOMD 1Lift T 1-3, Seq22-24 Elem1	12	01MAY01	16MAY01
18T2-32101	F/RP SOMD 1st Lift,Seq 25-27 Roof T 4-6Elem1	10	14MAY01	25MAY01
18T3-32101	F/RP SOMD 1st Li RoofT7-Can Elem1Seq34	10	29MAY01	11JUN01
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 Elem1Seq34	14	14JUN01	27JUN01
Form/Rebar/Pour SOMD 2nd Lift				
18T1-32201	F/RP SOMD 2nd Li Roof,Seq22-24,T1-3 Elem1	9	31JAN01	12FEB01
18T2-32201	F/RP SOMD,Seq 25-27 2nd Li RoofT 4-6Elem1	9	13FEB01	23FEB01
18T3-32201	F/RP SOMD 2nd Li RoofT7-Can Elem1Seq34	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

Figure 10. Modified Gantt Chart in Primavera P3



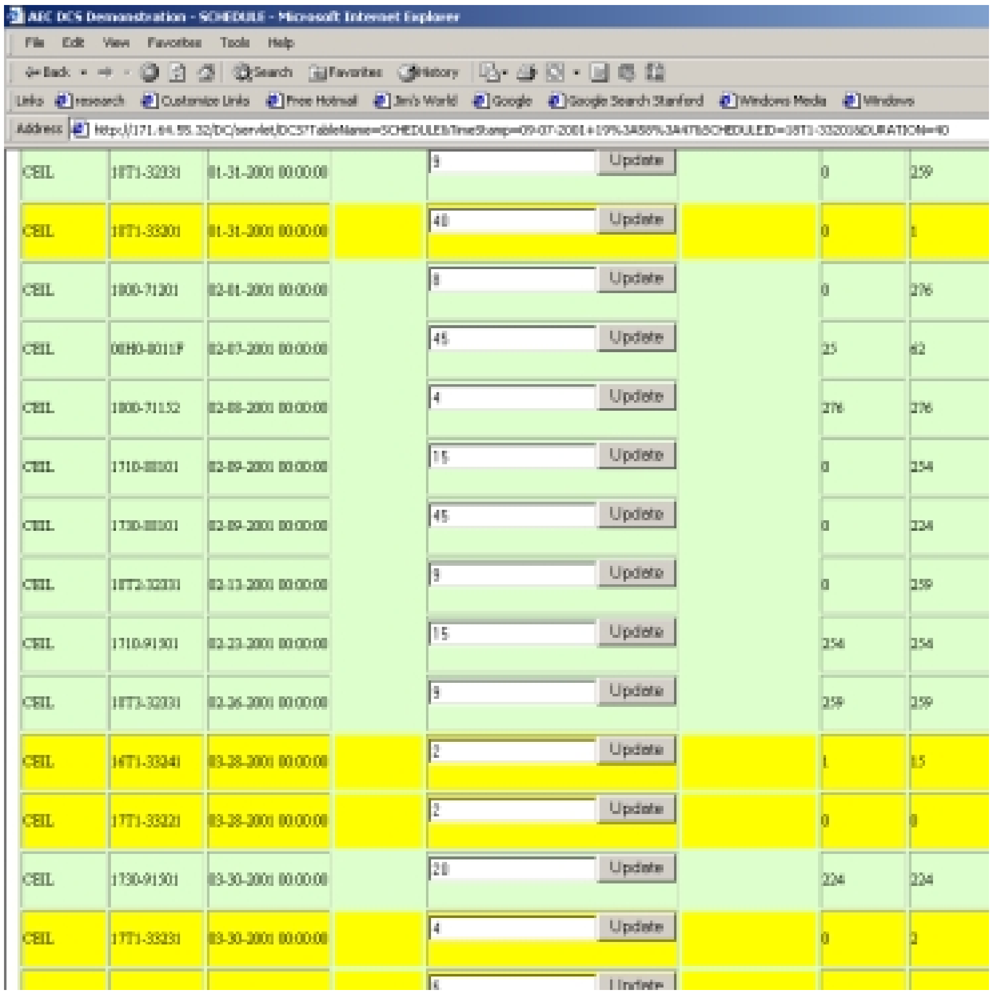
ACTIVITY	ES	EF	TYPE	CODE	TF
Design Element 1 Ceiling Attachements	01/03/00	02/27/01	MILESTONE	00H0-8011D	
Fab & Del Element 1 Ceiling Panels	07/27/01	09/28/01	MILESTONE	00H0-8011F	
Prep&Submit Element 1 Ceiling Panels	01/31/01	04/24/01	MILESTONE	00H0-8011S	
Design Element 1 Ceiling Panels	07/12/00	03/13/01	MILESTONE	00H0-8012D	
Erect Interior Scaffold S 1/3 - Lvl 1 Elem1	05/30/01	06/22/01	MILESTONE	1110-88101	35
Erect Interior Scaffold M 1/3 - Lvl 1 Elem1	08/02/01	08/24/01	MILESTONE	1120-88101	28
Erect Interior Scaffold N 1/3 - Lvl 1 Elem1	10/10/01	11/01/01	MILESTONE	1130-88101	0

Figure 11. Modified 4D Model Taken on 3/25/2001 From 4Dviewer



	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

Figure 12. Modified Gantt Chart in MS Project (Generated from PSL file)


AEC DCS Demonstration - SCHEDULE - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Links research Customize Links Free Hotmail Jim's World Google Google Search Stanford Windows Media Windows
Address

http://171.64.55.32/DC/servlet/DCS?TableName=SCHEDULE&TimeStamp=09-07-2001+10%3A58%3A47&SCHEDULEID=18T1-33200&DURATION=40

CEIL	18T1-32331	01-31-2001 00:00:00		9	Update		0	259
CEIL	18T1-33201	01-31-2001 00:00:00		40	Update		0	1
CEIL	1800-71201	02-01-2001 00:00:00		8	Update		0	276
CEIL	08H0-8011F	02-07-2001 00:00:00		45	Update		25	62
CEIL	1800-71152	02-08-2001 00:00:00		4	Update		276	276
CEIL	1710-88101	02-09-2001 00:00:00		15	Update		0	254
CEIL	1730-88101	02-09-2001 00:00:00		45	Update		0	224
CEIL	18T2-32331	02-13-2001 00:00:00		9	Update		0	259
CEIL	1710-91501	02-23-2001 00:00:00		15	Update		254	254
CEIL	18T3-32331	02-26-2001 00:00:00		9	Update		259	259
CEIL	16T1-33241	03-28-2001 00:00:00		2	Update		1	15
CEIL	17T1-33221	03-28-2001 00:00:00		2	Update		0	0
CEIL	1730-91501	03-30-2001 00:00:00		20	Update		224	224
CEIL	17T1-33231	03-30-2001 00:00:00		4	Update		0	2
				6	Update			

Figure 13. View Modified Project Information on Web Browser

PSL Reasoning

The underlying grammar used for PSL is based on KIF (Knowledge Interchange Format). KIF is a formal language based on first-order logic. All the knowledge about one project could be stored in PSL file, regarding whether it is from P3, Microsoft Project, Vite or 4D Viewer. Since all the terms in PSL are formally defined using first order logic, we can use some reasoning tool to reasoning on the knowledge base. From the reasoning, we can:

- Detect conflict in the knowledge database. It could be some simple conflict that could be easily detected by human being or some software. It could also be some deep logic conflict in the knowledge database that is hard to detect, since the project knowledge could come from heterogeneous resources.

- Identify the source of conflict and maintain the consistency of knowledge database. After we detected the conflict, we can trace back to the source of conflict and even solve the confliction.

- Infer some interesting conclusions, which might be not obvious. When project information comes from heterogeneous sources, some important project characteristics might not be obvious. However, reasoning tool can infer interesting conclusions from existing project information and help project manager to understand the project better.

The picture below (Figure 14) illustrates the basic reasoning process. First we infer some new conclusions from existing knowledge base. For the new knowledge, we will rewrite it and check whether it is subsumed by existing knowledge. If not, we could add the new knowledge to the knowledge base. Otherwise, we just delete it. Usually, the reasoning will stop either it find some conflict or no more conclusion could be inferred.

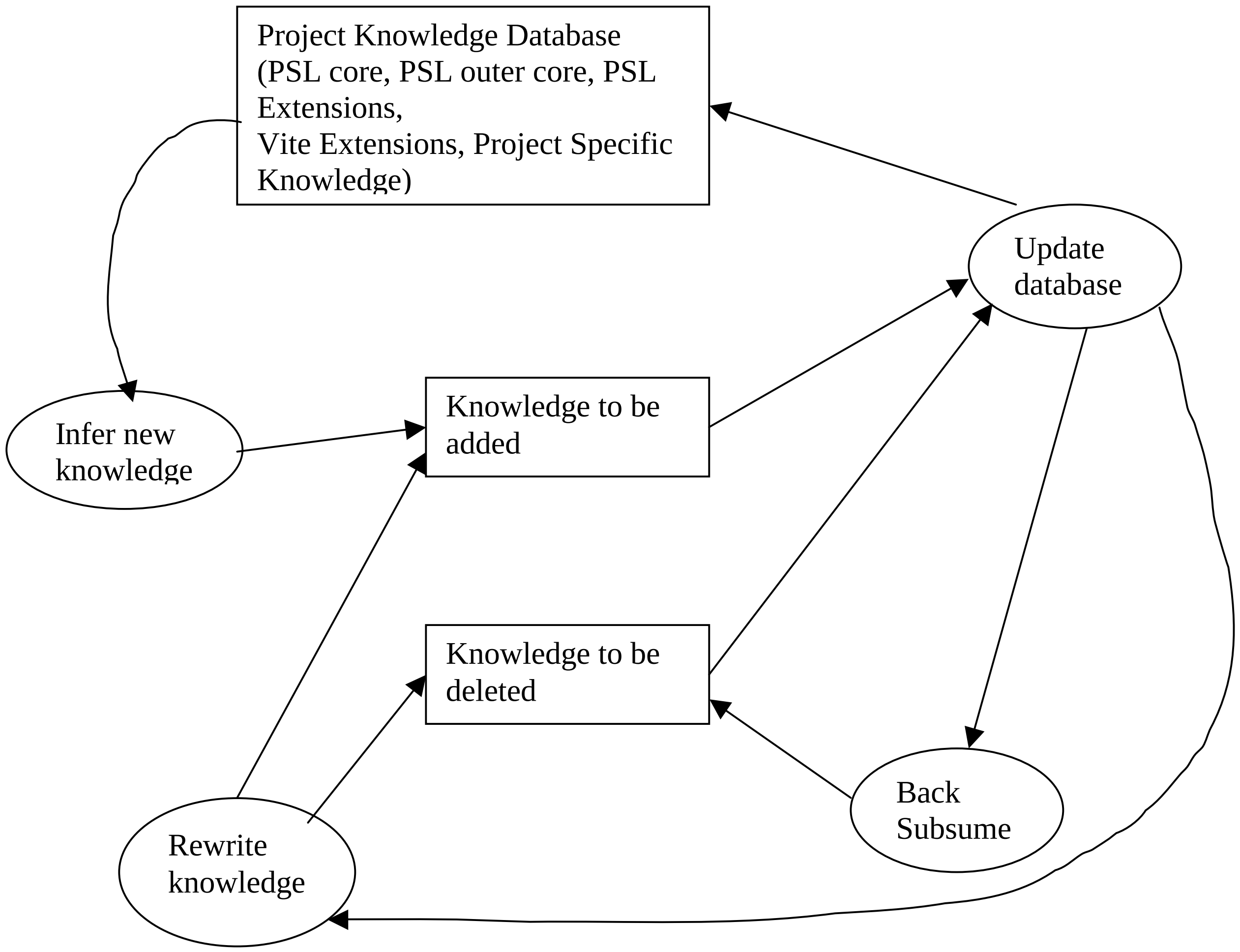

Project Knowledge Database (PSL core, PSL outer core, PSL Extensions,
Vite Extensions, Project Specific Knowledge)
Update database
Infer new knowledge
Knowledge to be added
Knowledge to be deleted
Back Subsume
Rewrite knowledge

Figure 14. Reasoning on PSL knowledge

The knowledge base where the reasoning tool is going to reason on includes two main parts:

- Axioms and definitions from PSL Core, PSL outer core, PSL Extensions and Vite Extensions
- Facts of individual project form heterogeneous resources

The reasoning among the axioms and definitions is not our interest. That reasoning not only produces a lot of uninteresting results but also significantly slows the reasoning process. Instead, we focus on the reasoning among the knowledge of specific project, and the reasoning between specific project knowledge and those axioms and definitions.

At the first step, we use Otter to reason on some sample project. Otter (Organized Techniques for Theorem-proving and Effective Research) is a resolution-style theorem-proving program for first order logic with equality. Otter includes the inference rules such as binary resolution, hyperresolution, UR_resolution, and binary paramodulation. It takes two types of input: logic clause or first order logic sentences. Since PSL is based on first order logic, it is very easy to convert PSL file into first order logic sentences, which Otter could read. Here is an example that we use Otter to detect inconsistency of PSL knowledge:

```
16 [] -activity_occurrence(x11)|occurrence_of(x11,$f1(x11)).
19 [] -occurrence_of(x19,x20)| -duration(x19,x21)| -
beginof(x19,x22)|endof(x19,x21+x22).
39 [] -after_start(x71,x72,x73)| -occurrence_of(x71,x74)| -occurrence_of(x72,x75)| -
endof(x71,x76)| -beginof(x72,x77)|x76<=x77.
51 [] activity_occurrence(AssembleverifyRTL).
52 [] beginof(AssembleverifyRTL,42300).
53 [] duration(AssembleverifyRTL,8640).
54 [] after_start(AssembleverifyRTL,FullChipSynth,Tutorial).
76 [] activity_occurrence(FullChipSynth).
77 [] beginof(FullChipSynth,30940).
115 [hyper,51,16] occurrence_of(AssembleverifyRTL,$f1(AssembleverifyRTL)).
125 [hyper,76,16] occurrence_of(FullChipSynth,$f1(FullChipSynth)).
139 [hyper,115,19,53,52,demod] endof(AssembleverifyRTL,50940).
144 [hyper,125,39,54,115,139,77,demod,propositional] $F.
```

From the example above, we can see that there are some conflictions in the project knowledge base. Following the proof process, we can trace back to the root of confliction, identify and solve the inconsistency problem in the project.